MODERN MANAGEMENT BASED ON BIG DATA III

Proceedings of MMBD 2022

Edited by
Antonio J. Tallón-Ballesteros

MODERN MANAGEMENT BASED ON BIG DATA III

Data is the basic ingredient of all Big Data applications, and Big Data technologies are constantly deploying new strategies to maximise efficiency and reduce the time taken to process information.

This book presents the proceedings of MMBD2022, the third edition of the conference series Modern Management based on Big Data (MMBD). The conference was originally scheduled to take place from 15 to 18 August 2022 in Seoul, South Korea, but was changed to a virtual event on the same dates. Some 200 submissions were received for presentation at the conference, 52 of which were ultimately accepted after exhaustive review by members of the programme committee and peer-reviewers, who took into account the breadth and depth of the research topics and the scope of MMBD. Topics covered include data analytics, modelling, technologies and visualization, architectures for parallel processing systems, data mining tools and techniques, machine learning algorithms, and big data for engineering applications. There are also papers covering modern management, including topics such as strategy, decision making, manufacturing and logistics-based systems, engineering economy, information systems and law-based information treatment, and papers from a special session covering big data in manufacturing, retail, healthcare, accounting, banking, education, global trading, and e-commerce. Big data analysis and emerging applications were popular topics.

The book includes many innovative and original ideas, as well as results of general significance, all supported by clear and rigorous reasoning and compelling evidence and methods, and will be of interest to all those working with Big Data.

MODERN MANAGEMENT BASED ON BIG DATA III

Frontiers in Artificial Intelligence and Applications

The book series Frontiers in Artificial Intelligence and Applications (FAIA) covers all aspects of theoretical and applied Artificial Intelligence research in the form of monographs, selected doctoral dissertations, handbooks and proceedings volumes. The FAIA series contains several sub-series, including 'Information Modelling and Knowledge Bases' and 'Knowledge-Based Intelligent Engineering Systems'. It also includes the biennial European Conference on Artificial Intelligence (ECAI) proceedings volumes, and other EurAI (European Association for Artificial Intelligence, formerly ECCAI) sponsored publications. The series has become a highly visible platform for the publication and dissemination of original research in this field. Volumes are selected for inclusion by an international editorial board of well-known scholars in the field of AI. All contributions to the volumes in the series have been peer reviewed.

The FAIA series is indexed in ACM Digital Library; DBLP; EI Compendex; Google Scholar; Scopus; Web of Science: Conference Proceedings Citation Index – Science (CPCI-S) and Book Citation Index – Science (BKCI-S); Zentralblatt MATH.

Volume 352

Recently published in this series

Modern Management based on Big Data III

Proceedings of MMBD 2022

Edited by

Antonio J. Tallón-Ballesteros

University of Huelva, Huelva city, Spain

IOS Press

LEGAL NOTICE

The publisher is not responsible for the use which might be made of the following information.

PRINTED IN THE NETHERLANDS

Preface

Data is the basic ingredient of Big Data (BiD) applications. BiD technologies are deploying new strategies to maximise efficiency and reduce the time taken to process information. Currently, we continue to work against the COVID-19 pandemic and the emerging COVID-22 wave.

The third edition of the conference series Modern Management based on Big Data (MMBD) has taken place as MMBD2022.

The general topics covered at the MMBD2022 conference fell into three main categories: big data, modern management and big-data-driven manufacturing and service industry supply chain (sc) management. Among other things, the first of these includes data analytics; big data modelling; big data technologies; data visualization; architectures for massively parallel processing systems; data mining tools and techniques; machine learning algorithms for big data; and big data for engineering applications. The second, modern management, encompasses modern management and strategy; management decision making; manufacturing and logistics-based systems; engineering economy; management information systems; human gender engineering; and law-based information treatment. The last group includes big data in manufacturing sc; big data in retail and healthcare; big data in accounting and banking sc; big data in educational sc; big data in global trading; and big data in e-commerce.

Apart from these general topics, as a follow-up to MMBD2021, MMBD2022 has attracted a number of papers related to COVID-19, including some hot topics but not limited to platform economy; innovations in online education management with big data; innovation and technology management; blockchain management and technology; green supply chain management; big data analytics in supply chains; policy and strategy for new energy and environment; smart grid load and energy management; sustainable traffic management; decision making on sustainable transport policies; modern healthcare management; modern food security management; social strategies for managing human relationships; and detecting fake news with mathematics and big data.

The MMBD2022 conference was originally scheduled to be held from 15–18 August 2022 in Seoul, South Korea. The most popular topics in this book concern big data analysis and emerging applications.

All papers were exhaustively reviewed by members of the programme committee and peer-reviewers, who took into account the breadth and depth of the research topics falling under the scope of MMBD. The 52 most promising and FAIA-mainstream-relevant contributions of some 200 submissions are included in this book. They present innovative and original ideas or results of general significance supported by clear and rigorous reasoning and compelling new light in terms of evidence, as well as method.

I would like to thank all the keynote and invited speakers, authors and anonymous reviewers whose efforts have resulted in MMBD becoming a top-level conference. I am also very grateful to those people, particularly the members of the programme committee and reviewers, who devoted their time to the assessment of the papers. It has been an honour to work from the outset on the publication of these proceedings in the prestigious series Frontiers in Artificial Intelligence and Applications (FAIA) from IOS Press. Our particular thanks also go to J. Breuker, N. Guarino, J.N. Kok, R. López de Mántaras,

J. Liu, R. Mizoguchi, M. Musen, S.K. Pal and N. Zhong, the FAIA series editors, for their support for this conference.

Last but not least, any inconvenience caused due to the change of format from face to face to virtual is sincerely regretted. Hopefully we will meet face to face at the MMBD2023 conference next year, the venue of which may be any convenient city in mainland China.

August 2022

Antonio J. Tallón-Ballesteros
University of Huelva (Spain)
Huelva city, Spain

About the Conference

The 3rd International Conference on Modern Management based on Big Data (MMBD2022) was originally scheduled to be held at Seoul, South Korea, however, considering the uncertainty caused by the global pandemic of COVID-19, MMBD2022 has changed to be held fully online via Microsoft Teams without onsite participants at Seoul, South Korea during August 15th-18th, 2022, organized by Keimyung University. Any inconvenience is sincerely regretted.

All papers were consciously reviewed by program committee members and peer-reviewers and beard in mind the breadth and depth of the research topics that fall into MMBD scopes. From about 200 submissions among MMBD, 52 most promising and FAIA mainstream-relevant contributions were included in this book, which present original ideas or results of general significance supported by clear reasoning and compelling evidence, and methods.

General Chair

Prof. Dr. Yoonmin Kim, Department of Economics and Finance, Keimyung University, South Korea; Vice Director at Asia Center & Vice Director for FTA Specialist Education Program, Keimyung University, South Korea

TPC Co-Chair

Prof. Dr. Md. Mamun Habib, School of Business, Independent University, Bangladesh; Visiting Scientist, University of Texas - Arlington (UTA), USA
Prof. Changjun Yi, Executive Vice-Dean, Business School of Huaqiao University, China

Technical Program Committee (TPC)

Dr. Emel Aktas, Professor, School of Management, Cranfield University, UK
Dr. Luis-Alberto Casado-Aranda, Assistant Professor, Department of Marketing and Market Research, University of Granada, Spain
Dr. Omid M. Ardakani, Associate Professor, Parker College of Business, Georgia Southern University, USA
Dr. Fuad Aleskerov, Professor, National Research University Higher School of Economics (HSE University), Russian Academy of Sciences, Russia
Dr. Antonio J. Tallón-Ballesteros, Department of Electronic, Computer Systems and Automation Engineering, University of Huelva, Spain
Dr. Cristian Barra, Assistant Professor of Economic Policy (tenure track), Department of Economics and Statistics (DISES), University of Salerno, Italy
Dr. Farshad Badie, Professor, Berlin School of Business and Innovation, Germany
Dr. Chi-Hua Chen, Distinguished Professor, College of Computer and Data Science, Fuzhou University, China

Dr. Ying Wang, Senior Lecturer in Finance, Faculty of Business and Law, Anglia Ruskin University, UK

Dr. Elaheh Yadegaridehkordi, Senior Lecturer, Center for Software Technology and Management, Faculty of Information Science and Technology, The National University of Malaysia (Universiti Kebangsaan Malaysia (UKM)) , Malaysia

Dr. Peng-Yeng Yin, Distinguished Professor, Department of Information Management, National Chi Nan University

Dr. Ran Zhang, Professor, Business School, Renmin University of China, China

Peer Reviewers

Dr. Li Bo, Associate Professor, School of Management, Tianjin University of Technology, China; the postdoctoral fellow at the Institute of Geographic Sciences and Natural Resources Research, the visiting scholar at Thomson University, Canada

Dr. Mingzhou Yu (Stanley), Assistant Professor, SHU-UTS SILC Business School, Shanghai University, China

Dr. Manuela Nechita, Naval Architecture Faculty, Dunarea de Jos University of Galati, Romania

Dr. Jakkrit Thavorn, Chulalongkorn University, Thailand

Dr. Babu Rao Gona, Assistant Professor in Economics at Dr Abdul Haq Urdu University, India

Dr. Neeraj Gupta, N. L. Dalmia Institute of Management Studies and Research, Mumbai, India

Dr. Chitradevi D, Hindustan Institute of Technology and Science (HITS), India

Dr. Bányai Tamás, Faculty of Mechanical Engineering and Informatics, University of Miskolc, Hungary

Dr. Bashir Ahmad, Professor, Dean Management and Social Sciences / Professor Management Science, DHA Suffa University, Pakistan

Dr. Gais Alhadi Babikir, University of Gezira, Sudan

Dr. Kamlesh Kumar Maurya, IMS Unison University, Dehradun, Uttrakhand, India

Dr. Wenyan Pan, Associate Professor, School of Management, Wuhan University of Technology, Wuhan, China

Dr. Elena Vasilyeva, Moscow State Unversity of Civil Engineering, Russia

Dr. Marios Dominikos Kremantzis, School of Management, University of Bristol, UK

Dr. Elaheh Yadegaridehkordi, Senior Lecturer, Center for Software Technology and Management, Faculty of Information Science and Technology, The National University of Malaysia (Universiti Kebangsaan Malaysia (UKM)) Selangor, Malaysia

Dr. Meng Li, Hefei University of Technology, China

Dr. Pawel Tadeusz Kazibudzki, Department of Business Management, e-Business and Electronic Economy, Faculty of Economics and Management, Opole University of Technology, Poland

Dr. Luca Esposito, University of Salerno, Italy

Dr. Apinporn Methawachananont, National Electronics and Computer Technology Center (NECTEC) National Science and Technology Development Agency (NSTDA) 112 Thailand Science Park, Thailand

Dr. Cristian Barra, Assistant Professor of Economic Policy (tenure track) Department of Economics and Statistics (DISES) University of Salerno, Italy

Dr. María-Dolores Guillamón, University of Murcia, Department of Financial Economics and Accounting, Faculty of Business Administration (B409) 30100 – Espinardo, Murcia, Spain

Dr. Hung-Che Wu, Associate Professor, Nanfang College of Sun Yat-sen University, China

Dr. Yousef Farhaoui, Department of Computer Science, Faculty of sciences and Technic, Moulay Ismail University, Errachidia, Morocco

Dr. Cláudia Aparecida Avelar Ferreira, Administration- Pontificial University Catholic of Minas Gerais, Brazil

Dr. Asmae Abadi, Professor, Mechanical and Industrial Engineering at INSA Euro-Méditerranée / UEMF, Morocco

Dr. Gaurav Joshi, Associate Professor, Marketing Management at Lal Bahadur Shastri Institute of Management, New Delhi, India

Dr. Xiaoyu Liu, Department of Management, Beijing Electronic Science& Technology Institute, China

Dr. Parvathaneni Naga Srinivasu, Department of Artificial Intelligence and Machine Learning, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, Telangana, India

Dr. Sheeraz Ahmed, Professor, Director ORIC in Iqra National University, Peshawar, Pakistan

Dr. L. Arun Raj, Department of Computer Science and Engineering B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai-48, India

Dr. Margherita Mori, Professor, University of L'Aquila, Italy

Dr. Chih-Chin Liang, Professor, Department of Business Administration, National Formosa University, Taiwan

Dr. B Valarmathi, Associate Professor, Department of Software and Systems Engineering, School of Information Technology and Engineering, VIT University, Vellore, India

Dr. Arti Jain, Department of Computer Science & Engineering at Jaypee Institute of Information Technology (JIIT), Noida, Uttar Pradesh, India

Dr. Kasim A. Alomari, Associate Professor, University of ThiQar, College of Engineering, Iraq

Dr. Renjith V Ravi, M.E.A Engineering College, Kerala, India

Dr. Sandy Kyaw, Senior Lecturer, Department of Accounting, Economics, and Finance, Cardiff Metropolitan University, UK

Dr. Massimiliano Kaucic, Department of Economics, Business, Mathematics and Statistics, University of Trieste, Italy

Dr. Najat Qader, Omar Kirkuk University, Iraq

Dr. Costas Siriopoulos, Zayed University, UAE

Dr. Fuad Aleskerov, Professor, Higher School of Economics, National Research University; Institute of Control Sciences, Russian Academy of Sciences, Russia

Dr. Massimo Merlino, Professor, San Marino University, Italy

Dr. Dalia AL-Eisawi, Assistant Professor of Business Technology and Analytics Princess, Sumaya University for Technology, Jordan

Dr. Trang Nguyen, Faculty of Information Technology, Ho Chi Minh City Open University, Ho Chi Minh 700000, Vietnam

Dr. Aleksandra Frolovskaia, Professor, Department of Building Structures and Controlled Systems, Siberian Federal University, Krasnoyarsk, Russian Federation

This page intentionally left blank

Contents

This page intentionally left blank

Elastic Trust Management in Decentralized Computing Environments

Hiroyuki SATO [1] and Yepeng DING
The University of Tokyo, Japan.

Abstract. Today, the Internet trust is a critical framework that forms a fundamental premise for network security. Several identity federations are deployed to embody the classic theory of trust framework. However, in an emerging blockchain-based decentralized system, we need to model dynamically grown/shrunken trust. This paper models the trust elasticity by formalizing PDP(policy decision point)s of enrolling entities and introducing Trust PDP. In the proposed formalization, assertions are exchanged among participating nodes to express the knowledge of the PDP of nodes. The knowledge may grow by exchanging assertions. Furthermore, we propose exchanging assertions on the trust relationship to express the elasticity of trust. The judgment on trust is operated by Trust PDP that affects the elasticity of trust. The proposed theory is applied to the trust establishment of blockchain and an authorization management system based on blockchain. The trust in the blockchain environment is expressed in terms of Trust PDP.

Keywords. elastic trust, trust establishment, trust framework, PDP (policy decision point), Trust PDP, blockchain, decentralized system

1. Introduction

Today, the Internet trust is a critical framework that forms a fundamental premise for network security. A site or an organization accepts communications from those trusted using a contract or a framework in advance. Namely, to making the Internet trust effectively work, the policies of trust must be explicitly specified. Furthermore, entities enrolling into the community are bound by contract. Servers accept communications by obeying thus specified policies. This is modeled by the classic theory of trust framework. In addition, typical criteria of trust have been developed [1] that are the basis of the deployment of several identity federations such as eduGain (https://www.edugain.org), inCommon (https://incommon.org/federation), and GakuNin (https://www.gakunin.jp).

Generally, modern distributed or decentralized systems obey certain logic to determine whether a designated server accepts a service request. They may be explicit or implicit, but one certain thing is that the complexity is becoming uncontrollable. In a classic model, this logic is managed and operated by given PDPs (policy decision point) and PEPs (policy enforcement point). However, in an emerging blockchain-based decentralized system, we cannot assume such a centralized trust framework. The trust is local to an enrolling node that must extend its trust by consensus with peers.

Considering the trust of blockchain-based decentralized systems, we see that the trust is never static, but elastically grows or shrinks depending on dynamic factors such

---

[1]Corresponding Author: Hiroyuki Sato, The University of Tokyo; Email: schuko@satolab.itc.u-tokyo.ac.jp.

as communications history, consensus with other nodes and environmental change by join/leave of nodes. In order to model this kind of trust construction, we need to model the elasticity of trust.

Modern Internet architectures have evolved so that services are provided to a large number of participants, data is produced by a number of IoT nodes, and managed in a completely distributed way. Blockchain is a typical system used for such a scenario. In such a new kind of scenario, trust is managed in a decentralized way, and therefore negotiations for trust become complicated. To resolve this kind of possible trust chaos, the trust construction must still obey pre-specified rules that include those how nodes enroll into the network, how they leave it, and how trustworthy the produced data is. We have to note that thus constructed trust is still local to the enrolling nodes that may lack the capability of global trustworthy communications. Elevating the local trust to the global trust is mandatory. In this meaning, classic trust framework cannot be applied to this scenario because the evaluation of global trust levels must be based on dynamic trust-related behaviors of enrolling entities.

In the classic trust framework, the policies on service, security and trust are decided and enforced by participating RP (Relying Party)s. An RP receives a service request under its own service policies. A received request is evaluated by its PDP in the context of request for the policies of the RP. Along this line, we consider their extension of this scheme so that an RP can accept arbitrary data for making policy decision. This kind of additional data is generally called "assertion." In the classic trust framework, assertions are mainly used for security reasons. On the side of an RP, Sato[2] has proposed a model in which an RP accepts a service request accompanied with related assertions. The accepting RP runs its policies under which the received assertions are evaluated. If the evaluation are trustworthy, the collected assertions will be elevated to evidence. Assertions may include general documents that may represent operation policies or current behavior of a client, which an RP can also use to make an allow/deny decision.

In the same way, we extend the logic that express the range of trusted nodes whose assertions will be elevated to evidence. In a distributed or decentralized system, nodes may arbitrarily join and/or leave. This extend logic is a meta-logic to PDP.

We summarize our scenario in Fig. 1. A PDP of a node can enrich its policies by exchanging assertions with other nodes in a given trust circle **(a)**. Assertions can include policies that are evaluated and included by the PDP to enrich the inference of the node. Second, the trust circle can grow or shrink when a node joins or leaves it. This elasticity is expressed to be consistent with the inference within the trust circle **(b)**. This framework of elasticity is applied to a blockchain-based system **(c)** to show its effectiveness.

We start by modeling the knowledge exchange among the nodes that trust each other (modeling of classic trust frameworks) and extend the model to express the elasticity of trust. This theory is from [3], and will be applied to a decentralized system.

The rest of this paper is organized as follows. In Sect. 2, we give a formalization of knowledge exchange by using assertions in a general distributed system. In Sect. 3, we extend it to express the trust elasticity. In Sect. 4, we apply the proposed theory to blockchain scenarios. Sect. 5 surveys related work. Finally, Sect. 6 concludes this paper.
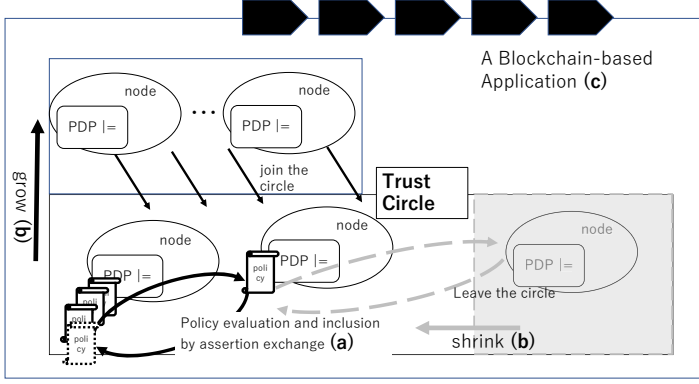
Figure 1. Goal and Application Scenario of the Elastic Trust

2. Formal Definitions of Trust and PDP

In [3], we have modeled a distributed system in which each knowledge and trust of an enrolling node grows or shrinks by exchanging "assertions." We first sketch it, emphasizing the role of PDPs.

A distributed environment is defined as a collection of entities e that communicates with other nodes in $e.env$. Its policy decision *Allow* or *Deny* is inferred and made on the basis of $e.pol$, the policy set of PDP, and $e.trust$, the set of trusted nodes and assertions. In the inference, a property can be an assertion of knowledge of e. $assert(e, \lceil P \rceil)$ for entity e and property P represents that the entity e claims the property P. Here, $\lceil P \rceil$ is a term for the internal representation of a given property P.

Definition 1 (Trust) The trust of e is a set of pairs of an entity and assertion: $\{(e_1, \lceil assert(e_1, \lceil P_1 \rceil) \rceil), \cdots, (e_n, \lceil assert(e_n, \lceil P_n \rceil) \rceil)\}$. Using A, a set of assertions, an entity e infers a property P. We denote it by $A \models^e P$. The inference is the first order logic that assumes $P \in e.pol$ and the following rule of assertions:

if $e.trust \ni (f, \lceil assert(f, \lceil P \rceil) \rceil), A \ni \lceil assert(f, \lceil P \rceil) \rceil$, then $A \models^e assert(f, \lceil P \rceil)$ and $A \models^e P$.

The intention of rules of *assert* is that when a node e accepts an assertion, its internal representation as data is translated into a policy. In this way, a policy is sent to another node. As its result, a set of assertions as policies trusted by an entity may grow during the communications with other entities in $e.env$ or shrink by invalidation of assertions (e.g. expiration). The rule on *assert* claims that the data $\lceil P \rceil$ is expanded to be used as property P in the inference of an accepting PDP. We note that the premise of inference may grow by communications with other entities.

It is often the case that an entity sends its policy set to another entity whose PDP is expected to evaluate it. Assuming that all policies are available in the a machine-readable form, Sato [4] gives a model in which policies of a peer such as security and privacy can be directly processed as data, and sent to a peer PDP. In our formalization, the machine-readable policy set $\{P_1, P_2, \cdots, P_n\}$ of an entity e is maintained as a collection of assertion

data $\{\lceil assert(e, \lceil P_1 \rceil) \rceil, \cdots, \lceil assert(e, \lceil P_n \rceil) \rceil\}$ and can be exchanged within *e.env*. This enables the dissemination of policies among nodes to share the same policy set.

However, we must note that the decision "policy" of PDP whether an entity accepts an assertion from a specific entity is not yet discussed, which will be discussed in the next section.

3. Elastic Trust and Logic of Trust PDP

So far, an entity is assumed to communicate with a fixed set of peer entities in a given trust circle. In decentralized systems, no entity knows the set of entities existing in the world. An entity may come into or leave another entity's view at any time. In such an environment, dynamically controlling the trust, monitoring the environment is indispensable. In our system, we consider this policy for monitoring and controlling the environment of a given entity as a "meta" policy of PDP that is dynamically controlled by Trust PDP (TPDP). This dynamically growing/shrinking trust is called *Elastic Trust* in this paper, and controlled by TPDP.

Under the control of TPDP, by specifying a set of trustworthy assertions S, and executing $create(S, TP, P)$, an entity e can create a uniquely identifiable entity in *e.env* where TP represents the TPDP policy, or TPDP properties defined below and P the PDP policy of the created entity. The name of a created entity belongs to at least one name space where the created name is unique.

A TPDP property is defined as a formula of the first order logic on $trust(t, S)$, $join(t, S)$, $created(e, t, S, TP, P)$ and $leave(t, S)$ for a entity t and a set of assertions S for *trust*, *join* and *leave* and for entities e, t, S a set of assertions, TP a set of TPDP properties, and P a set of properties for *Created*. As in a PDP property, $assert(t, \lceil P \rceil)$ for an entity t and a TPDP property P is also used.

As the entailment in TPDP properties in an entity e, we use the same logic for PDP. The properties *join* and *leave* in TPDP policies correspond to *Allow* and *Deny* in PDP policies, respectively.

Actions taken by some entity (i.e. *join* and *leave*) affects the trust status of other entities. Trust status is represented by a set of assertions that the entity trusts. It shows elasticity, that is, it can grow or shrink dynamically. An entity claims its own trust status by continuously issuing its TPDP assertions. These assertions determine growth and shrink of the entity's trust *e.trust*. We define the elasticity as the trust status transition as:

Definition 2 (Elasticity)   • A trust status of an entity e is defined as a tuple (e, TP, T, TA) where TP represents a trust policy comprising of a set of TPDP properties, T the trust of e, and TA a sequence of TPDP assertions.
   • We denote by $(e, TP, T, TA) \Rightarrow (e, TP, T', TA')$ that TA, changes to TA', and T to T' accordingly,
$(e, TP, T, TA) \Rightarrow (e, TP, T', TA')$ is defined reflecting the semantics of *created*, *join* and *leave*. Typically, If TA' is TA with $\{\lceil assert(t, \lceil join(s, B) \rceil) \rceil \}$ concatenated, and $join(s, B)$ can be inferred in TP, then $T' = T \cup (\{s\} \times B)$.

Receiving TPDP assertions. e modifies *e.trust*. In other words, the trust status (e, TP, T, TA) (T = *e.trust*) of a given environment is continuously updated. When *e.trust* is modified, the inference of PDP is modified. In this meaning, the trust status of e shows

$$\textbf{TPDP} : (e, TP, T, TA) \implies (e, TP, T', TA')$$

$$\downarrow(\textbf{determines}) \qquad\qquad \downarrow(\textbf{determines})$$

$$\textbf{PDP} : T = e.trust \models^e \xrightarrow{\text{(update)}} T' = e.trust \models^e$$

Figure 2. Hierarchical Transition of Trust Status of TPDP and PDP

transition. According to *join* and *leave* actions, *e.env*, the set of entities that can communicate with *e*, is updated to contain or remove *s* with its related assertions. Figure 2 summarizes the two-layer trust status transition of PDP and TPDP. In the figure, we note that $\longrightarrow$ and $\implies$ are commutative.

As applications of this system, typical scenarios of blockchain and trust update by environment monitoring are analyzed in [3].

4. Elastic Trust for Blockchain Scenarios

Recently, blockchain technologies have been widely used to construct decentralized computing environments to enhance integrity and availability. A blockchain is an immutable distributed ledger based on a consensus mechanism enforced by all decentralized nodes to agree on transactions, which can be generally categorized into permissionless blockchain and permissioned blockchain. The trust among nodes varies in blockchain types.

Unlike permissionless blockchains, permissioned blockchains are governed by authorities to partially decentralize systems with trade-offs for the administration that provide trust among nodes. With the node trust assumption, permissioned blockchains can adopt consensus mechanisms like Raft[5] that have better performance than permissionless blockchains.

Our elastic trust model can be used to analyze trust in blockchain scenarios from the infrastructure level, like formalizing the trust establishment in permissioned blockchains, to the application level, like reasoning about decentralized authorization frameworks. In this section, we analyze the authorization system on the blockchain bearing [6] in mind.

4.1. Trust Establishment of Consortium Blockchains

A consortium blockchain is a type of permissioned blockchain that allows the existence of authorities to govern the network. Depending on the consortium blockchain platform, authorities can usually authenticate nodes for consensus to introduce trust.

In our scenario, a set of authorities (governors) $g_i \in G, i \in N$ governs a consortium blockchain. Each authority g_i provides and maintains a set of nodes $C_i, |C_i| > 1$ for consensus, which composes an authenticated node set $\hat{C}$. All nodes in $\hat{C}$ only process transactions from authenticated sources and reject any other transactions, i.e., trust is established only among all authenticated nodes. We also allow authorities to control the num-

ber of provided nodes dynamically. An authority g_i can authenticate new nodes to join the consensus and remove old nodes to mark them as unauthenticated.

For brevity, we formulate the trust establishment process for an authority $g_i \in G$ as follows. All other authorities in G follow the same process.

1. g_i is created with its PDP policy $\{g_j \mid j \in N, j < |G|\} \times \top$ and trust environment $g_i.env = G \setminus g_i$;

2. For each $c \in C_i$, g_i issues an assertion set $\{\lceil assert(g_i, \lceil created(g_i, c, \top, \{g_i\} \times \top, \emptyset)\rceil)\rceil\rceil, \lceil assert(g_i, \lceil join(c, \top)\rceil)\rceil\}$ to itself, which creates a node c with the TPDP policy $\{trust(g_i, \top)\}$ and the PDP policy $\{g_i\} \times \top$. Meanwhile, the PDP policy and trust environment of g_i are updated;

3. For all $c \in C_i$, c has the initial trust status $trust_{init} = \{g_i\} \times \top$ and dynamically updates its trust status by continually receiving TPDP assertions from g_i as follows.

$$(c, TP_c, trust_{init}, \emptyset) \implies$$
$$(c, TP_c, trust_{init} \cup (\{c_j \mid j \in N, j < |C_i|\}), TA_{g_i}) \implies \ldots$$

4. g_i publishes assertion sets $\{\lceil assert(g_i, \lceil created(g_i, c, \top, \{g_i\} \times \top, \emptyset)\rceil)\rceil \mid c \in C\}$ and $\{\lceil assert(g_i, \lceil join(c, \top)\rceil)\rceil \mid c \in C\}$ to all $g_j \in G, i \neq j$;

5. For all assertion sets received from $g \in G$, g_i updates its trust status and sends them to all $c \in C_i$;

6. For all $c \in C_i$, c updates its trust status with TPDP issued by $g_j \in G, i \neq j$ from g_i and update its trust environment.

After the trust is fully established, authorities trust each other and nodes trust authenticated node set $\hat{C}$ because of their trust to owners. A node can judge the source of a transaction by evaluating its TPDP policies and PDP policies. When a node c_m receives a transaction from a client, it will transmit the processed transaction information τ to other nodes as an assertion $\lceil assert(c_m, \lceil received = \tau\rceil)\rceil$. When the received transaction is processed by a node $c_n \in \hat{C}$, c_m will have an assertion $\lceil assert(c_n, \lceil received = \tau\rceil)\rceil$. c_m will issue $\lceil assert(c_m, \lceil assert(c_n, \lceil received = \tau\rceil)\rceil)\rceil$ and send to other nodes that have established trust with c_m. If the trust between c_m and c_n has been established, then c_m can simplify the assertion as $\lceil assert(c_m, \lceil received = \tau\rceil)\rceil$.

In the case when an authority g_i appends a new node c to the network, g_i will issue assertions $\lceil assert(g_i, \lceil created(g_i, c, \top, \{g_i\} \times \top, \emptyset)\rceil)\rceil$ and $\lceil assert(g_i, \lceil join(c, \top)\rceil)\rceil$. Similar to the trust establishment process, authorities in A and nodes in $\hat{C}$ will update their trust status and trust environments.

On the contrary, if an authority g_i removes a node c from the network, g_i will issue an assertion set $\{\lceil assert(g_i, \lceil leave(c, \top)\rceil)\rceil\}$ to all authorities in G including itself. When g_i delivers the TPDP assertion set, the trust status of g_j changes $(g_j, TP, T, TA) \implies (g_j, TP, T \setminus (\{c\} \times \top), TA + \{\lceil assert(g_i, \lceil leave(c, \top)\rceil)\rceil\})$.

In this manner, the consortium blockchain can establish and dynamically change trust among nodes.

4.2. Blockchain-Based Authorization Framework

Authorization frameworks have evolved into a new stage with the support of blockchain technologies. Studies [6,7] have proposed practical approaches to implementing autho-

rization mechanisms with smart contracts, a type of program deployed and executed on blockchains. Here, we show how our elastic trust model can be used to reason about decentralized authorization frameworks.

A decentralized authorization framework mechanizes trust between resource providers and resource consumers into a smart contract running on either a permissionless blockchain or a permissioned blockchain. A state of the smart contract can be abstracted by a function $\mathscr{S} : R \mapsto S$, where R is a set of resources registered by resource providers and S is a set of trust status. For a resource $r \in R$, we have $\mathscr{S}(r) = (r, TP, T, TA)$. Here r is identified by its wallet address $W(r)$, TP and T are defined in the contract storage, and TA can be constructed by assertion change logs stored in the event storage.

A resource provider p_i can register a set of resources R_i by issuing assertion sets $\{\lceil assert(p_i, \lceil created(p_i, r, \top, \{p_i\} \times \top, \emptyset)\rceil)\rceil, \lceil assert(p_i, \lceil join(r, \top)\rceil)\rceil\}$ where $r \in R_i$. For each registered resource r, r is created with its TPDP policy $\{trust(p_i, \top)\}$ and its PDP policy $\{p_i\} \times \top$. To authorize resource consumer u to access resource r, p_i can issue a TPDP assertion $\lceil assert(p_i, \lceil join(u, Allow(u, r))\rceil)\rceil$. On the contrary, p_i can issue an assertion $\lceil assert(p_i, \lceil leave(u, Allow(u, r))\rceil)\rceil$ to prevent u from accessing resource r. Because, all resources $r \in R_i$ trust TPDP assertions from p_i, resources can give correct authorization responses by using records on the blockchain to evaluate access requests.

5. Related Work

For constructing a trust framework, policies play a critical role in establishing the trust relationship among participants. P3P[8] was the framework that evaluated the published policy of Web servers. Partially inspired by the idea of P3P, the direct evaluation of security and privacy policies are proposed[2]. The policy evaluation framework is another facet of this study. In addition to ordinary audit and assessment, evidence based policy evaluation has been studies especially in health care systems[9].

In modern distributed computing environments where stakeholders enroll and leave dynamically and the network architecture is based on local connections, the security context and the related security policy assessment may dynamically change. One typical example includes supply chain. The hierarchical evaluation of policies [10] has been proposed to handle this locality. IoT environments are the second typical example. IoT device management is discussed with blockchain combined[11]. [12] is a hierarchical construction of blockchain. IoTeX (https://iotex.io) is another hierarchical blockchain-based management of IoT devices in which several functions have been proposed [13, 14]. Its trust is also discussed[15]. [16] uses the Ethereum platform instead of IoTeX. [17] is another example that adopts independent platform for controlling IoT. Together with our blockchain-based system, the trust analysis of these systems needs dynamism, which is one of the application fields of our theory.

6. Concluding Remarks

In this paper, we have extended the theory of classic trust frameworks in order to express the elastic trust typically seen in blockchain based decentralized system. The trust is formalized for an environment where enrolling nodes exchange properties by using asser-

tions. An assertion of a given property is represented by using the internal representation. The trust elasticity is represented by join and leave of nodes.

Furthermore, we have applied the proposed theory to consortium blockchain and to a blockchain-based authorization system. The system of trust elasticity is represented, and how it is used in the authentication has been shown. In such a scenario, consensus is the source of trust that is reflected in TPDP. The formal analysis of TPDP together with its relation to consensus is our next step.

In collecting a huge number of data, the heterogeneity of the related trust directly affect the construction of trust. Trust elasticity is one of key factors in the management of data and trust.

References

[1] Grassi P, Fenton J. Digital authentication guideline. Technical Report SP800-63-3: NIST; 2017.

[2] Sato H, Tanimoto S, Kobayashi T, Kanai A. Adaptive Policy Evaluation Framework for Flexible Service Provision. In: Proceedings of 2018 IEEE Symposium on Service-Oriented System Engineering; 2018 Mar; Oxford, UK: IEEE; p. 124–131.

[3] Sato H, Yamamoto N. Elastic Trust Model for Dynamically Evolving Trust Frameworks. Trans IEICE. 2019 Sep; E102-D(9):1617–1624.

[4] Sato H, Tanimoto S, Kanai A. A Policy Consumption Architecture that enables Dynamic and Fine Policy Management. In: Proceedings of 3rd ASE International Conference on CyberSecurity; 2014 Jun; Palo Alto, CA: ASE.

[5] Howard H, Schwarzkopf M, Madhavapeddy A, Crowcroft J. Raft Refloated: Do We Have Consensus? SIGOPS Operating Systtems Review. 2015 Jan; 49 (1):12-–21.

[6] Ding Y, Sato H. Bloccess: Towards Fine-Grained Access Control Using Blockchain in a Distributed Untrustworthy Environment. In: Proceedings of 8th IEEE International Conference on Mobile Cloud Computing, Services, and Engineering; 2020 Mar; Oxford, UK: IEEE; p.17–22.

[7] Ding Y, Sato H. Dagbase: A Decentralized Database Platform Using DAG-Based Consensus. In: 2020 IEEE 44th Annual Computers, Software, and Applications Conference; 2020 July; Madrid, Spain: IEEE; p.798–807.

[8] Olurin M Adams C Logrippo L. Platform for privacy preferences (P3P): Current Status and Future Directions. In: Proceedings of 2012 Tenth Annual International Conference on Privacy, Security and Trust; 2012 Jul; Paris, France: IEEE; p. 217–220.

[9] Kuchenmüller T, Chapman E, Takahashi R, Lester L, Reinap M, Ellen M, Haby M. A Comprehensive Monitoring and Evaluation Framework for Evidence to Policy Networks. Evaluation and Program Planning. 2022 April; 91:102053. Volume 91, 2022,

[10] Tanimoto S, Watanabe Y, Sato H, Kanai A. Two-Tier Trust Structure Model for Dynamic Supply Chain Formulation. In: Proceedings of Advanced Informaion Networking and Applications 2022 (LNNS 451); 2022 April; Sydney, Australia:Springer; p. 324—333.

[11] Dai H.-N, Zheng Z, Zhang Y. Blockchain for Internet of Things: A Survey. IEEE Internet of Things Journal. 2019 Oct; 6(5):8076–8094.

[12] Lei K, Du M, Huang J,Jin T. Groupchain: Towards a Scalable Public Blockchain in Fog Computing of IoT Services Computing. IEEE Trans on Services Computing, 2020 March-April; 13(2):252–262.

[13] Fan X, Chai Q, Li Z, Pan T. Decentralized IoT Data Authorization with Pebble Tracker. In; Proceedings of 2020 IEEE 6th World Forum on Internet of Things (WF-IoT); 2020 June; New Orleans, LA: IEEE; p. 1–2.

[14] Partida A, Criado R, Romance M. Identity and Access Management Resilience against Intentional Risk for Blockchain-Based IOT Platforms. Electronics. 2021 Feb; 10(4):378.

[15] Boncea R, Petre I, Vevera V. Building Trust among Things in Omniscient Internet using Blockchain Technology. Romanian Cyber Security J. 2019 Spring; 1(1):25–33.

[16] Leal M, Pisani F, Endler M. A Blockchain-based Service for Inviolable Presence Registration of Mobile Entities. J. Brazil Comput Soc. 2021 Jan; 27(1).

[17] Hu J, Reed MJ, Al-Naday M, Thomos N. Hybrid Blockchain for IoT-Energy Analysis and Reward Plan. Sensors. 2021 Jan; 21(1):305.

Nonparametric Estimation of the Production Frontier Using a Data-Fitting Technique

Yu ZHAO [a,1]

[a] *School of Management, Department of Management, Tokyo University of Science*

Abstract. We propose a novel nonparametric approach for estimating the production frontier based on a data-fitting technique. The proposed approach allows for stochastic noise and provides decision-makers with a general and flexible estimation procedure to support and facilitate the decision-making process in the stochastic context. A major feature of the proposed approach is that the estimation procedure is completely nonparametric and easy to implement. Similar to other existing nonparametric approaches, our proposed approach results in an estimate of the piece-wise linear production frontier. In contrast to the existing ones, the evaluation of each data point is performed within a unit-specific data range. We also propose a naive method for determining the data ranges of each data point. The performance of our proposed approach is examined using various simulated scenarios. For each scenario, we compare our proposed approach with the existing methods, including the data envelopment analysis (DEA), the stochastic nonparametric envelopment of data (StoNED), and the stochastic frontier analysis (SFA). The simulation results suggest that our approach performs better than the existing methods in the single input and single output case. Our proposed approach can also be easily extended to a multi-input setting. Moreover, the proposed naive method on data ranges also shows its flexibility and usefulness in the simulated examples.

Keywords. production frontier, nonparametric estimation, data-fitting technique, downside deviation, stochastic noise

1. Introduction

Estimating production frontiers is essential for performance benchmarking and productivity analysis. The current approaches include the data envelopment analysis (DEA,e.g., [1,2]), the stochastic nonparametric envelopment of data (StoNED,e.g., [3, 4]), and the stochastic frontier analysis (SFA,e.g., [5,6]). DEA is a nonparametric method for measuring the relative efficiencies of peer decision-making units (DMUs). Because DEA ignores stochastic noise, the frontier estimated by DEA is entirely deterministic, suggesting that any deviations from the frontier (e.g., gauging the distance to the boundary of the production technology) can be considered a measure of pure inefficiency. By contrast, SFA is known as a general stochastic parametric approach. It accounts for

---

[1]Corresponding Author: Yu Zhao, School of Management, Department of Management, Tokyo University of Science, Japan; E-mail: yu.zhao@rs.tus.ac.jp

stochastic noise by treating all deviations from the frontier as aggregations of both inefficiency and noise. However, compared with the flexibility of nonparametric measurements, SFA relies heavily on an accurately pre-specified functional form for production technology. To combine both advantages of DEA (i.e., nonparametric estimation) and SFA (i.e., stochastic noise), StoNED has been introduced in the literature on efficiency analysis [7]. Because StoNED formulates a quadratic programming problem, solving large-scale problems requires more efficient computational algrithms [8].

This study proposes a nonparametric approach for estimating the production frontier. The proposed approach is based on a data-fitting technique and accounts for stochastic noise. The commonly used regression technique is easy to implement using ordinary least squares regression (OLS). A significant feature of the regression technique lies in that the estimated coefficients characterized a hyperplane passing the barycenter of all data points. Contrary to the regression lines (or hyperplanes), the production frontier identifies a set of maximum producible outputs at a given level of inputs. To obtain an upper bound of the observed level of outputs, we modify the OLS problem as a minimization problem of downside deviations [9] by restricting all residuals to be nonnegative. However, in practice, an infinite number of upper bounds could exist as it is challenging to observe the same DMU multiple times. Such an issue can be interpreted as a missing data problem. Methodologically, we propose a naive method that considers the similarity of the observed data point, and the upper bound of the observed point is estimated by using its neighborhood points. After the upper bound of each data point is estimated, the following procedure becomes a problem of choosing correctly estimated coefficients that can be used to construct a non-decreasing concave function. We show that such a problem can be solved by Afriat's inequalities [10]. Finally, we can derive an estimator of the piece-wise linear production frontier by using the lower bound of the maximum producible outputs corresponding to the selected estimated coefficients.

Recently, methods such as DEA, SFA, and StoNED have become important analytical tools in expert and intelligent systems that facilitate decision-making by policymakers or regulators (for recent relevant studies, see, e.g., [11,12,13,14]). This study provides an alternative approach for supporting the decision-making process from the methodological perspective. Moreover, our proposed approach overcomes several drawbacks of the existing approaches and provides decision-makers with a general and flexible modeling approach in the stochastic context. We will discuss this in detail in Sections 2 and 4.

The remainder of the paper is structured as follows. Section 2 reviews previous related research on the production frontier estimation. Section 3 provides methodological details. In Section 4, we use six simulated scenarios to examine the flexibility and usefulness of the proposed estimation procedure. Section 5 concludes the paper.

2. Literature review

This section briefly reviews major existing approaches for estimating production frontiers in the field of productivity analysis and efficiency measurement. Understanding the level of efficiency and productivity is essential for fostering continuous improvement of the production and operation management in a production activity (e.g., firm, school, government, nonprofit organization, etc.). During the past several years, the term "best

practice" has been widely used in both the theoretical and practical benchmarking literature. A popular idea for identifying best practices is to model the frontier of the production technology, which is a mathematical description of the relationship between inputs and outputs. The theoretical literature on production theory imposes several basic axioms of production technology, such as free disposability, convexity, and returns to scale (see, e.g., [10,15,16,17]). The frontier estimated in this study is non-decreasing and concave, which is consistent with the theoretical axioms of production theory.

The production frontier estimation can be implemented with DEA, SFA, or StoNED. Since the first DEA model was proposed in 1978 [1], there has been a rapid growth in the number of theoretical and practical DEA studies in various areas such as agriculture, banking, supply chain, transportation, and public policy, among others (see, e.g., [18,19, 20,21]). A major reason for this popularity lies in that the DEA method can measure various frontiers according to the different assumptions of returns to scale. Examples include the constant and variable returns-to-scale DEA frontiers (see, e.g., [1,2]). Note that the frontier estimated in this study is implicitly based on the variable returns-to-scale assumption. However, by dropping off the intercept term (i.e., α in Section 3), one can easily impose the constant returns-to-scale assumption. Compared with the DEA frontier, our approach allows the existence of stochastic noise while the DEA frontier envelopes all of the observed data as tightly as possible, which is purely deterministic.

On the other hand, both SFA and StoNED account for stochastic noise, and these methods allow the data outside the estimated frontier are outside by pure chance. According to the survey [22], the SFA frontier has also been widely used in many areas of applications, and the top five SFA research areas are banking, insurance, container ports, hospital/health care, and agriculture (see also [23] for a systematical review of empirical applications in SFA). A major drawback of SFA is that the SFA frontier is constructed by a pre-specified functional form such as the Cobb-Douglas, translog and generalized McFadden. In contrast to SFA, the StoNED frontier can be estimated nonparametrically (more precisely, semi-nonparametrically, as additional parametric assumptions will be required if one uses the method of moments or quasi-likelihood estimation to derive the frontier estimates). However, compared with the number of applications in DEA or SFA, there are few empirical studies using the StoNED, and most focus on banking, energy, and agriculture (see, e.g., [24,25,26]).

A significant feature of StoNED is that the convex nonparametric least-squares [3] is used to estimate the frontier, which is a problem with quadratic constraints (QCP). Several packages and solvers can be used for estimating the StoNED frontier, such as the "benchmarking" package in R, the "pyStoNED" package in python, QCP solvers in GAMS, and the "CVX" toolbox in Matlab. From a computing perspective, however, the standard estimation procedure of the StoNED frontier suffers from the computational burden even with relatively small sample sizes [27]. Moreover, previous studies on improving the computational performance of StoNED require the assumption of the additive composite error structure [8]. If the composite error structure is multiplicative (e.g., the simulated example using the univariate Cobb-Douglas model in Section 4), the StoNED estimation becomes a nonlinear programming problem, and the computational merits of the algorithm in [8] no longer hold.

Another existing stochastic nonparametric approach is called chance-constrained data envelopment analysis (CCDEA, see, e.g., [28,29,30]). The CCDEA approach shares with SFA and StoNED that some of the data variations may be noise. However, the esti-

mation problem requires strong assumptions on the noise terms, and the computational burden is bigger [31]. In this study, we only compare the performance of our proposed approach with DEA, SFA, and StoNED. Once the frontier is estimated, the existing metrics for the efficiency or productivity in the benchmarking literature, such as distance functions (e.g., [32,33]) or Malmquist-type indices (e.g., [34,35,36]), can be applied for further analysis.

3. Method

We propose a novel nonparametric approach for estimating the production frontier with consideration of inefficiencies and random noise. To introduce the basic idea, we begin with the description of the theoretical model for a single input and single output case.

Considering a sample of n DMUs, each of them produces a single output $y_i \in \mathbb{R}_+$ with a single input $x_i \in \mathbb{R}_+$ for $i = 1, \ldots, n$. The production function is denoted by $f : \mathbb{R}_+ \to \mathbb{R}_+$. We assume that f is a continuous, non-decreasing, and concave function. Let $u_i \in \mathbb{R}_+$ and $v_i \in \mathbb{R}$ be the nonnegative inefficiency term and random noise, respectively. Formally,

$$
\begin{aligned}
y_i &= f(x_i) - u_i + v_i \\
&= f(x_i) + \varepsilon_i, \qquad i = 1, \ldots, n,
\end{aligned}
$$

where $\varepsilon_i = v_i - u_i$ is a composite error term. We also assume that u_i and v_i are independent of each other as well as of x_i for all $i = 1, \ldots, n$.

For any observed point (x_i, y_i), the tangent line of $f(x_i)$ represents the upper bound of x_i. Consider the following minimization problem:

$$
\min \sum_{i=1}^{n} (\alpha + \beta x_i - y_i)^2 \tag{1}
$$

$$
\text{s.t. } \alpha + \beta x_i - y_i \geq 0, \quad i = 1, \ldots, n \tag{2}
$$

$$
\beta \geq 0. \tag{3}
$$

Let $e_i := \alpha + \beta x_i - y_i$ for all $i = 1, \ldots, n$ and let $(\hat{e}_i, \hat{\alpha}, \hat{\beta})$ be the optimal solution to the problem (1)–(3). We call $\hat{e}_i$ the estimated downside deviation of the point (x_i, y_i), and $y_i + \hat{e}_i (= \hat{\alpha} + \hat{\beta} x_i)$ is then referred to as the estimated upper bound of (x_i, y_i). It can be proved that the estimated upper bound is independent of the choice of $(\hat{e}_i, \hat{\alpha}, \hat{\beta})$ (For details of the proof, see Theorem 1 in [9]). The difference between the problem (1)–(3) and the ordinary least squares regression is illustrated below: In Figure 1, we plot a sample of 100 points that are produced with a common production technology $y = x^{0.5}$ where the composite error term follows from $u \sim Exp[\mu = 1/6]$ with μ representing the expected inefficiency and $v \sim N(0, 1/6)$. The red line passing through the barycenter of all points is the regression line estimated by the ordinary least squares. By contrast, the blue dashed line results from the problem (1)–(3) and envelopes all points.

Our purpose is to estimate the unknown function f in a nonparametric approach. We consider the problem of estimating the tangent line of $f(x)$ at any given (x_i, y_i) such as
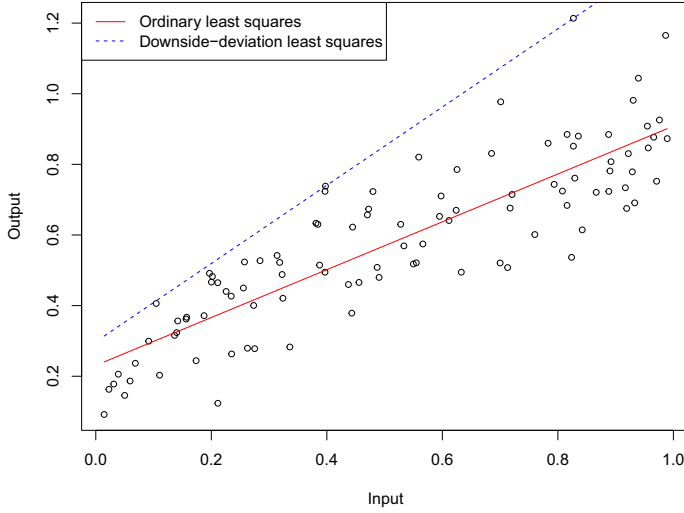
Figure 1. Illustration of the downside-deviation least squares

$$\min \sum_{i \in G_i} (\alpha + \beta x_i - y_i)^2 \tag{4}$$

$$\text{s.t. } \alpha + \beta x_i - y_i \geq 0, \quad i \in G_i \tag{5}$$

$$\beta \geq 0, \tag{6}$$

where G_i is an index set for the range of the observed point (x_i, y_i) and $\bigcup_{i=1}^{n} G_i = \{1, \ldots, n\}$. The set G_i can be determined based on a priori information about the production function. In this paper, we propose a naive method for determining G_i for the purpose of clarification. For some pre-assigned number $1 \leq k \leq n$, define

$$G_{min}(i) := \max(i - k, 1), \quad i \in \{1, \ldots, n\} \tag{7}$$

$$G_{max}(i) := \min(i + k, n), \quad i \in \{1, \ldots, n\}. \tag{8}$$

The set G_i is then represented by $[G_{min}(i), G_{max}(i)]$. If $k = n$, the problem (4)–(6) coincides with the problem (1)–(3).

The problem (4)–(6) implicitly estimates the upper bound for any observed point (x_i, y_i) at a given range G_i. Let $(\tilde{\alpha}, \tilde{\beta})$ be the optimal solution of (x_i, y_i). Solving the problem (4)–(6) for n observed points leads to n estimated coefficients (i.e., $(\tilde{\alpha}_i, \tilde{\beta}_i), i = 1, \ldots, n$). To further impose the concavity assumption, we apply the following Afriat's theorem [10]:

Theorem 3.1 (Afriat's inequalities)**.** *For n observations and m inputs $\boldsymbol{x} = (x_1, \ldots, x_m)^{\top}$, the following statements hold:*
(1) There exists a continuous concave function $f : \mathbb{R}^m \to \mathbb{R}$ that satisfies $y_i = f(\boldsymbol{x}_i)$ in a

finite number of points $i = 1, \ldots, n$.

(2) There exists finite coefficients $\alpha_i, \boldsymbol{\beta}_i = (\beta_{1i}, \ldots, \beta_{mi})^\top$ such that $y_i = \alpha_i + \boldsymbol{\beta}_i^\top \boldsymbol{x}_i$ for $i = 1, \ldots, n$, that satisfy the following system of inequalities:

$$\alpha_i + \boldsymbol{\beta}_i^\top \boldsymbol{x}_i \leq \alpha_h + \boldsymbol{\beta}_h^\top \boldsymbol{x}_i, \quad \text{for } i, h = 1, \ldots, n \text{ and } i \neq h.$$

In the single input and single output case ($m = 1$), the concavity assumption is

$$\alpha_i + \beta_i x_i \leq \alpha_h + \beta_h x_i, \quad \text{for } i, h = 1, \ldots, n \text{ and } i \neq h. \tag{9}$$

Let $I(i, i) := \{(\tilde{\alpha}_i, \tilde{\beta}_i) \mid i = 1, \ldots, n\}$ be the set of optimal solutions of the problem (4)–(6) for all observed points. Define

$$\bar{\bar{I}}(i, i) := \begin{cases} I(i, i) & \tilde{\alpha}_i + \tilde{\beta}_i x_i \leq \tilde{\alpha}_h + \tilde{\beta}_h x_i \\ I(h, h) & \tilde{\alpha}_i + \tilde{\beta}_i x_i > \tilde{\alpha}_h + \tilde{\beta}_h x_i \end{cases} \tag{10}$$

for $i, h = 1, \ldots, n$ and $i \neq h$. The set $\bar{\bar{I}}(i, i)$ contains the estimated coefficients that can be used to constructed a concave function f.

Using $(\tilde{\alpha}_i, \tilde{\beta}_i) \in \bar{\bar{I}}(i, i)$, the estimated outputs are computed by $\tilde{y}_i = \tilde{\alpha}_i + \tilde{\beta}_i x_i$, $\forall i$. We then construct the production frontier with the lower bound of the estimated outputs:

$$\tilde{f}(x) := \min\{\alpha + \beta x \mid \alpha + \beta x_i \geq \tilde{y}_i, \forall i\}. \tag{11}$$

Figure 2 illustrates how the production frontier can be determined using the proposed estimation procedure. In Figure 2, we randomly generated 100 data points using the function $y = x^{0.5}$ (i.e., the solid black line). By using a pre-assigned number $k = 4$, we solve the problem (4)–(6) for each data point and the size of range G_i belongs to the set $\{5, 6, 7, 8, 9\}$ (See, Eqs. (7)–(8)). By further imposing the concavity assumption, the upper bounds for determining the frontier are finally reduced to five lines (i.e., the dashed lines). Consequently, the frontier is estimated as the lower bound of those five dashed lines (i.e., the red lines). It can be seen that our proposed approach estimates a piece-wise linear production frontier.

Let J be the number of points satisfying $y_i \leq \tilde{f}(x_i)$, $\forall i$. Then $\rho := J/n$ represents the ratio of the observed points enveloped by the estimated frontier in the whole observed points. If $k = n$, we have $\rho = 100\%$. Suppose the interest is in estimating a frontier that envelops 80% observed points. In that case, one can start by selecting $k = 1$ and repeat the estimation procedure by changing the value of k until $\rho \geq 80\%$ is achieved.

4. Simulations

In this section, we compare the performance of the proposed approach with the existing methods: DEA, StoNED, and SFA. We consider six scenarios similar to the previous studies [4,37]. To clarify the significant difference between our proposed approach and existing ones, we report the results of the index ρ and the standard mean squared error (MSE) of each method. The notations used in this section are defined below:
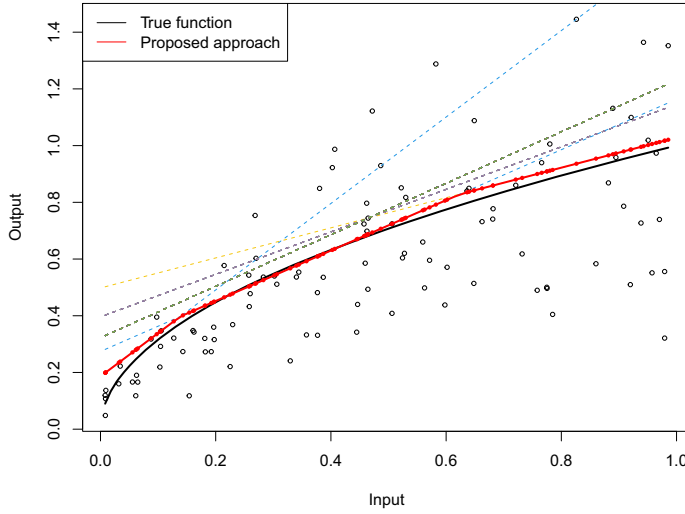
Figure 2. Illustration of the estimated piece-wise linear production frontier

$$\rho_{\hat{f}} = \frac{\text{number of the points under the estimated frontier } \hat{f}}{\text{total number of the points}} \times 100\%,$$

where $\hat{f}$ denotes the true function f or the frontier function estimated by our proposed method, StoNED, SFA, or DEA. The MSE statistic is

$$MSE_{\hat{f}} = \frac{1}{n} \sum_{i=1}^{n} (\hat{f}(x_i) - f(x_i))^2.$$

For the purpose of clarification, we consider the following univariate Cobb-Douglas model:

$$y_i = x_i^{0.5} \exp(-u_i) \exp(v_i), \tag{12}$$

where $x_i \sim Uni[0,1]$, $u \sim Exp[\mu = 1/6]$ with μ representing the expected value of u_i and $v \sim N(0, \sigma_v^2)$ where $\sigma_v^2 = p \times \mu$ and p represents the noise-to-signal ratio. If $p = 0$, the stochastic noise will be assumed away, which is not the interest of our study. Among the various parametric production functional forms, the Cobb-Douglas model characterizes a concave production function and is commonly used in the SFA literature. Following the previous studies [4,37], we use the univariate Cobb-Douglas frontier as the true frontier and consider six different scenarios for comparing the performance of our proposed approach with DEA, SFA, and StoNED.

Table 1 reports the results of the index $\rho_{\hat{f}}$. Because of the existence of stochastic noise, the generated random sample may appear above the true frontier. ρ_{true} shows the percentage of data under the true frontier. For example, scenario (a) randomly generated 100 points, and 76% of those are under the true frontier. Using this information, we

Table 1. Comparisons of the estimated production frontiers: Results of $\rho_{\hat{f}}$

Scenario	Description	ρ_{true}	$\rho_{proposed}$	ρ_{StoNED}	ρ_{SFA}	ρ_{DEA}
(a)	$n = 100, p = 1$	76	67 $(k = 5)$ 78 $(k = 4)$	55	81	100
(b)	$n = 100, p = 2$	62	54 $(k = 2)$ 69 $(k = 4)$	52	87	100
(c)	$n = 200, p = 1$	77	64 $(k = 7)$ 80 $(k = 9)$	50	85	100
(d)	$n = 200, p = 2$	69	64 $(k = 3)$ 70 $(k = 5)$	54	76	100
(e)	$n = 300, p = 1$	77	60 $(k = 10)$ 80 $(k = 11)$	49	87	100
(f)	$n = 300, p = 2$	67	52 $(k = 4)$ 73 $(k = 10)$	53	72	100

Table 2. Comparisons of the estimated production frontiers: Results of $MSE_{\hat{f}}$

Scenario	Description	$MSE_{proposed}$	MSE_{StoNED}	MSE_{SFA}	MSE_{DEA}
(a)	$n = 100, p = 1$	0.0006 $(k = 5)$ 0.0004 $(k = 4)$	0.0050	0.0009	0.0624
(b)	$n = 100, p = 2$	0.0032 $(k = 2)$ 0.0010 $(k = 4)$	0.0049	0.0297	0.1481
(c)	$n = 200, p = 1$	0.0074 $(k = 7)$ 0.0013 $(k = 9)$	0.0077	0.0017	0.0764
(d)	$n = 200, p = 2$	0.0039 $(k = 3)$ 0.0009 $(k = 5)$	0.0070	0.0038	0.4505
(e)	$n = 300, p = 1$	0.0042 $(k = 10)$ 0.0025 $(k = 11)$	0.0105	0.0026	0.0617
(f)	$n = 300, p = 2$	0.0058 $(k = 4)$ 0.0022 $(k = 10)$	0.0090	0.0016	0.2507

repeat the estimation procedure of our proposed method until $\rho_{proposed}$ gets closer to ρ_{true}. Moreover, we report two types of $\rho_{proposed}$ for each scenario: one is less than ρ_{true} and the other one is greater than ρ_{true}. As shown in Table 1, the frontier estimated by StoNED tends to be located on the lower side of the true frontier as $\rho_{StoNED} < \rho_{true}$ for all scenarios. By contrast, because $\rho_{SFA} > \rho_{true}$, the frontier estimated by SFA tend to be located on the upper side of the true frontier. The frontier estimated by DEA always envelops all data points because DEA ignores the stochastic noise. On the other hand, the frontier estimated by our proposed method can be very close to the true frontier if we choose the proper k. These observations can also be confirmed in Figure 3.

Table 2 further reports the results of $MSE_{\hat{f}}$. We obtain that $MSE_{proposed}$s of scenario (a)–(e) have smaller values than MSE_{SFA}, implying that our proposed method shows better performance than SFA in most scenarios. It is worth noting that we use the correct function to fit the SFA frontier for each scenario. Such an observation suggests that even the naive selection of k is useful in estimating the production frontier. Figure 3 further shows that our proposed method performs better than all other methods.
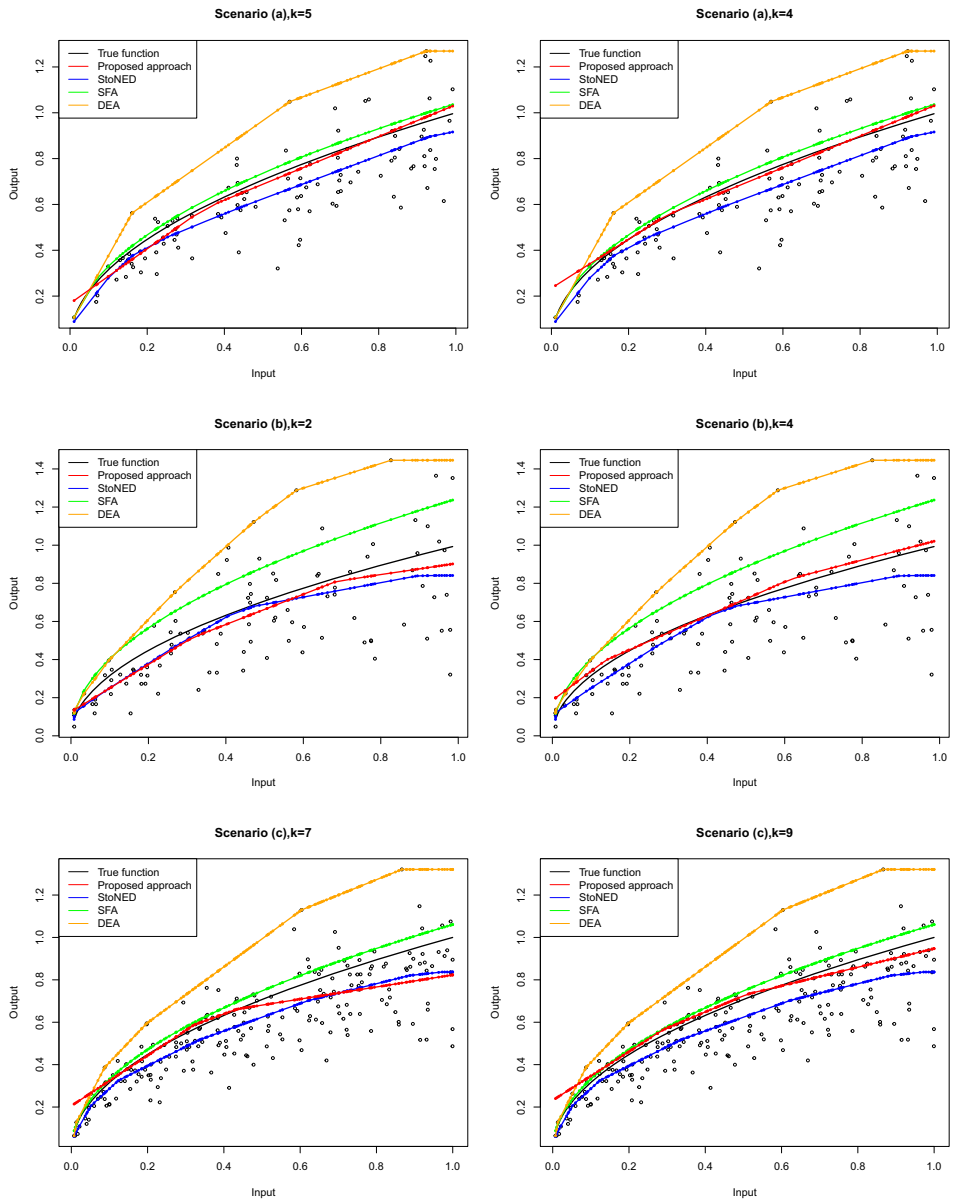
Figure 3. Estimated frontiers
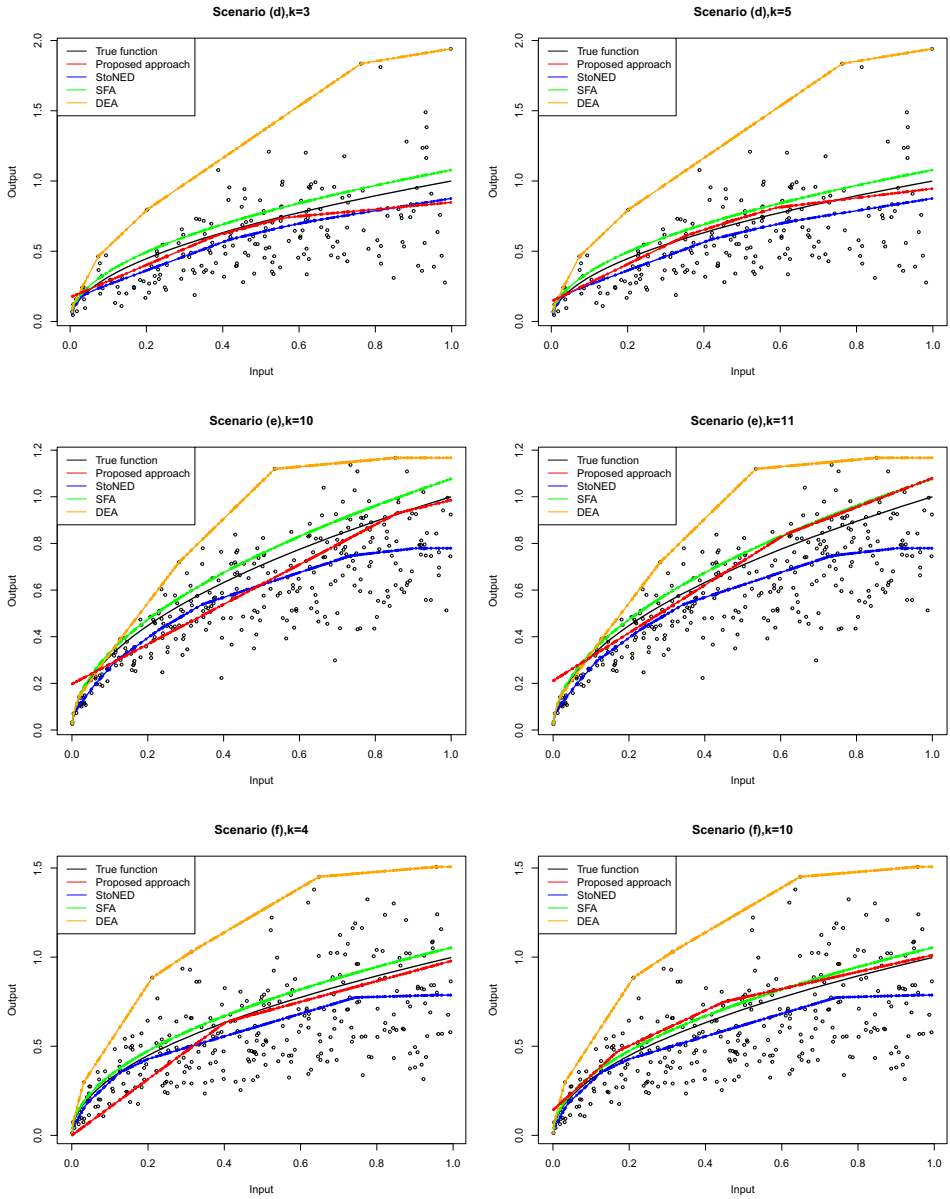
Figure 3. Estimated frontiers (continued)

5. Conclusions and future research

We propose a nonparametric approach for estimating a piece-wise linear production function based on a data-fitting technique. Previous studies usually use the parametric ap-

proach (e.g., SFA), the nonparametric approach (e.g., DEA), or the semi-nonparametric approach (e.g., StoNED). Our simulation results show that the proposed estimation procedure performs better than these existing ones. Compared with SFA, our proposed method does not rely on a pre-specific function and determines the production frontier in a completely nonparametric way. Compared with DEA, our proposed method accounts for the impact of stochastic noise. If the policy-makers or regulators have knowledge or information on the level of stochastic noise, the number k can be appropriately determined. Alternatively, researchers can obtain different estimates of production frontiers that envelop different data points by varying the number of k. Compared with StoNED, our proposed method is easy to implement and can be easily applied to large-scale problems. It is worth noting that StoNED requires additional parametric assumptions (e.g., method of moments, quasi-likelihood estimation) or the nonparametric kernel density estimator to determine the final estimate of the frontier. Another difference between StoNED and our proposed method is that the latter does not require further parametric assumptions.

The present paper focuses on a single input and single output case to clarify the estimation procedure. Our approach can be easily extended to a multi-input and single-output setting by replacing the single variable x with a vector $\boldsymbol{x}$ of length m. The applicability of a multi-input and multi-output setting needs to be investigated. On the other hand, methods for the decision of k should be further investigated. We propose a naive method to decide the number k in this paper, and our simulation results prove the usefulness of the proposed naive method. Extensions to empirical data are necessary for examining the adaptability of the proposed approach in future research. Furthermore, the relationship among our proposed method, DEA, and StoNED also needs to be investigated. Because both DEA and StoNED estimate a piece-wise linear frontier, our proposed method may produce the same frontier as DEA or StoNED with some designed DMU-specific range G_is. Finally, we hope this study can make inroads into empirical practice and believe the proposed idea can be helpful to policy-makers and regulators.

References

[1] Charnes A, Cooper WW, Rhodes E. Measuring the efficiency of decision making units. European journal of operational research. 1978;2(6):429-44.

[2] Banker RD, Charnes A, Cooper WW. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management science. 1984;30(9):1078-92.

[3] Kuosmanen T. Representation theorem for convex nonparametric least squares. The Econometrics Journal. 2008;11(2):308-25.

[4] Kuosmanen T, Kortelainen M. Stochastic non-smooth envelopment of data: semi-parametric frontier estimation subject to shape constraints. Journal of productivity analysis. 2012;38(1):11-28.

[5] Aigner D, Lovell C, Schmidt P. Formulation and estimation of stochastic frontier production function model specifications. Journal of Productivity Analysis. 1977;7:399-415.

[6] Meeusen W, van Den Broeck J. Efficiency estimation from Cobb-Douglas production functions with composed error. International economic review. 1977:435-44.

[7] Kuosmanen T, Johnson A, Saastamoinen A. Stochastic nonparametric approach to efficiency analysis: A unified framework. In: Data envelopment analysis. Springer; 2015. p. 191-244.

[8] Lee CY, Johnson AL, Moreno-Centeno E, Kuosmanen T. A more efficient algorithm for convex nonparametric least squares. European Journal of Operational Research. 2013;227(2):391-400.

[9] Sekitani K, Zhao Y. Performance benchmarking of achievements in the Olympics: An application of Data Envelopment Analysis with restricted multipliers. European Journal of Operational Research. 2021;294(3):1202-12.

[10]   Afriat SN. Efficiency estimation of production functions. International economic review. 1972:568-98.

[11]   Mohtashami A, Ghiasvand BM. Z-ERM DEA integrated approach for evaluation of banks & financial institutes in stock exchange. Expert Systems with Applications. 2020;147:113218.

[12]   Henriques IC, Sobreiro VA, Kimura H, Mariano EB. Two-stage DEA in banks: Terminological controversies and future directions. Expert Systems with Applications. 2020;161:113632.

[13]   Chen L, Wang YM. Limitation and optimization of inputs and outputs in the inverse data envelopment analysis under variable returns to scale. Expert Systems with Applications. 2021;183:115344.

[14]   Molinos-Senante M, Maziotis A. Benchmarking the efficiency of water and sewerage companies: Application of the stochastic non-parametric envelopment of data (stoned) method. Expert Systems with Applications. 2021;186:115711.

[15]   Hanoch G, Rothschild M. Testing the assumptions of production theory: a nonparametric approach. Journal of Political Economy. 1972;80(2):256-75.

[16]   Diewert WE, Parkan C. Linear programming tests of regularity conditions for production functions. In: Quantitative studies on production and prices. Springer; 1983. p. 131-58.

[17]   Varian HR. The nonparametric approach to production analysis. Econometrica: Journal of the Econometric Society. 1984:579-97.

[18]   Liu JS, Lu LY, Lu WM, Lin BJ. A survey of DEA applications. Omega. 2013;41(5):893-902.

[19]   Liu JS, Lu LY, Lu WM. Research fronts in data envelopment analysis. Omega. 2016;58:33-45.

[20]   Emrouznejad A, Yang Gl. A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016. Socio-economic planning sciences. 2018;61:4-8.

[21]   Kaffash S, Azizi R, Huang Y, Zhu J. A survey of data envelopment analysis applications in the insurance industry 1993–2018. European journal of operational research. 2020;284(3):801-13.

[22]   Lampe HW, Hilgers D. Trajectories of efficiency measurement: A bibliometric analysis of DEA and SFA. European journal of operational research. 2015;240(1):1-21.

[23]   Daraio C, Kerstens K, Nepomuceno T, Sickles RC. Empirical surveys of frontier applications: a meta-review. International Transactions in Operational Research. 2020;27(2):709-38.

[24]   Kuosmanen T, Kuosmanen N. Role of benchmark technology in sustainable value analysis: an application to Finnish dairy farms. Agricultural and Food Science. 2009;18(3-4):302-16.

[25]   Kuosmanen T. Stochastic semi-nonparametric frontier estimation of electricity distribution networks: Application of the StoNED method in the Finnish regulatory model. Energy Economics. 2012;34(6):2189-99.

[26]   Eskelinen J, Kuosmanen T. Intertemporal efficiency analysis of sales teams of a bank: Stochastic semi-nonparametric approach. Journal of Banking & Finance. 2013;37(12):5163-75.

[27]   Johnson AL, Kuosmanen T. An introduction to CNLS and StoNED methods for efficiency analysis: Economic insights and computational aspects. In: Benchmarking for performance evaluation. Springer; 2015. p. 117-86.

[28]   Land KC, Lovell CK, Thore S. Chance-constrained data envelopment analysis. Managerial and decision economics. 1993;14(6):541-54.

[29]   Olesen OB, Petersen N. Chance constrained efficiency evaluation. Management science. 1995;41(3):442-57.

[30]   Cooper WW, Huang Z, Lelas V, Li SX, Olesen OB. Chance constrained programming formulations for stochastic characterizations of efficiency and dominance in DEA. Journal of productivity analysis. 1998;9(1):53-79.

[31]   Olesen OB, Petersen NC. Stochastic data envelopment analysis—A review. European journal of operational research. 2016;251(1):2-21.

[32]   Shephard RW. Theory of Cost and Production Functions Princeton University Press. Princeton, New Jersey. 1970.

[33]   Färe R, Grosskopf S. Theory and application of directional distance functions. Journal of productivity analysis. 2000;13(2):93-103.

[34]   Malmquist S. Index numbers and indifference surfaces. Trabajos de Estadistica y de Investigacion Operativa. 1953;4(2):209-42.

[35]   Pastor JT, Lovell CK. A global Malmquist productivity index. Economics Letters. 2005;88(2):266-71.

[36]   Zhao Y, Morita H, Maruyama Y. The measurement of productive performance with consideration for allocative efficiency. Omega. 2019;89:21-39.

[37]   Simar L, Zelenyuk V. Stochastic FDH/DEA estimators for frontier analysis. Journal of Productivity Analysis. 2011;36(1):1-20.

Implementation of a Driving Simulator for the Collection of Data on Human Behavior in Vehicular Traffic

Joshua PROAÑO [a] and Paulina MORILLO [b] and Diego VALLEJO-HUANGA [b,1]

[a] *Department of Computer Science, Universidad Politécnica Salesiana*
[b] *IDEIAGEOCA Research Group, Universidad Politécnica Salesiana*

Abstract. Traffic psychology covers not only the act of driving but also includes inherent phenomena such as accidents, violations, and the generation of emotions. This article proposes the development of a driving simulator within the video game Grand Theft Auto V, taking advantage of the artificial intelligence of characters that interact with the player, as well as other drivers and pedestrians. The implementation includes the adaptation of steering wheel type controls and the creation of a mod in C# for data collection and export. This implementation seeks to obtain useful data for the analysis of the behavior of the drivers evaluated during the driving tests carried out in three virtual circuits within a city. By performing the tests with drivers of different levels of experience, it was possible to verify the effectiveness of the tool in its use and realism. According to the individuals evaluated, the simulator achieved an average realism of 4.6 on a Likert scale from 1 to 5. Likewise, the results obtained show that the data collected by the simulator is less biased than those obtained through a post-driving survey.

Keywords. Videogame, Traffic Psychology, Artificial Intelligence, Virtual Environment

1. Introduction

The invention of motor vehicles along with the development of the automotive industry brought about a revolution in the field of human mobility. This caused an increase in the number of drivers and cars on the roads, giving rise to the analysis and study of traffic [1]. Traffic analysis studies the behavior of different vehicles and their interaction with the environment and considers several variables, and its study involves various aspects such as weather conditions, the number of cars on the streets, the design and quality of the roads, and various aspects of driver psychology [2].

Driver behavior is an important aspect that influences traffic and has been investigated by several disciplines, its analysis involves macroscopic models aimed at obtaining general vehicle variables such as size and distance from other vehicles. Microscopic models take into account more specific variables, and their analysis is much more complex than that of macroscopic models, since they include variables such as the state of

---

[1]Corresponding Author: Diego Vallejo-Huanga, IDEIAGEOCA Research Group, Universidad Politécnica Salesiana, Rumichaca y Morán Valverde, Quito, Ecuador; E-mail: dvallejoh@ups.edu.ec

roads, signage, city design, road infrastructure [2], which will influence the actions a driver will take. Traffic psychology is a branch of applied psychology responsible for studying road infrastructure, driver and pedestrian behavior, and road education to address road accidents with a comprehensive and preventive approach, where all elements converge in driving [3].

With the introduction of experimental psychology and psychometrics, together with industrial and social advances, psychology assumes the multidisciplinary role that allows quantitative and qualitative analysis of data collected using assessment instruments [4]. Traffic psychology encompasses not only the act of driving, but including inherent phenomena such as accidents, violations, and the generation of emotions [1]. Thus, the types of emotions vary between subjects and are related to the experiences and their learning [5]. Another important factor within the psychology of driving is that the personality of each individual is variable and is affected by external factors. The individual's personality plays an predominant role since driving is an activity that requires a decision-making process in situations with a high degree of uncertainty [6].

There are several scientific investigations that have addressed the problem of traffic and driver behavior, based on their personality, using different methodologies [7] [8] [9]. These works try to model the behavior patterns of drivers, in everyday situations, and most of these have been carried out through real scenarios, using vehicles in established circuits. However, drivers may not drive as usual if they feel they are being monitored. A solution would be to monitor driving, without the subject feeling pressured, by using driving simulators [10].

Although there are several driving simulators on the market, only the most advanced ones can simulate real situations of drivers and pedestrians during the journey. Some of these simulators are priced between 3000 USD and above, and it is usually necessary to purchase additional software and hardware for the best experience [11]. The most affordable simulators do not usually generate interaction with pedestrians or other drivers and, therefore, are not an optimal solution. This work is developed with the aim of implementing a driving simulator as realistic as possible, which presents everyday situations and sensitive controls, allowing the collection of data on the driving behavior of the person driving for later analysis.

2. Materials and Methods

This section describes the hardware and software requirements necessary to implement the simulator. In addition, the development of the methods and classes used for the data acquisition of the video game, the adaptation of the controls, and the design of routes are presented.

2.1. Materials

The development of the simulator follows the methodology shown in Figure 1. Here, the relevant data, tools, and frameworks, necessary peripherals, and their adaptation are defined for an agile development cycle with functional prototypes.
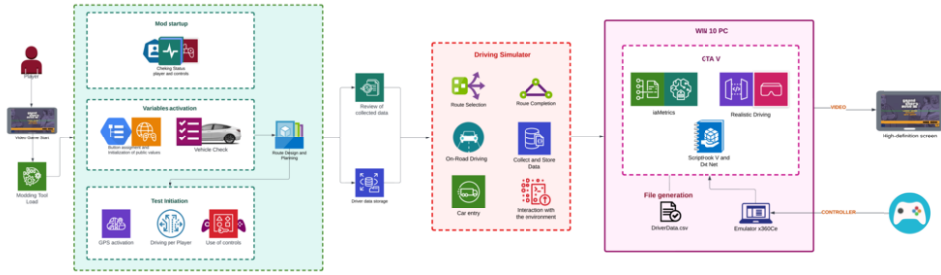
Figure 1. Block diagram of the methodology for mod development.

2.1.1. Hardware and Software Requirements

For this work, we considered the use of the video game Grand Theft Auto V developed by Rockstar North, which was released for seventh-generation consoles in 2013, for eighth-generation consoles in 2014, for Microsoft Windows in 2015, and for ninth-generation consoles in 2021. The story of this game takes place in the fictional city of Los Santos, which contains urban and rural environments, as well as an artificial intelligence designed to reproduce the behavior and attitudes of people and drivers. Thus, reproducing a realistic environment that allows drivers to behave in a natural way during the tests.

To allow the video game to run with a stable frame rate and without cuts or freezes, the developer company Rockstar proposes minimum and optimal hardware and software requirements. Taking into account the developers' recommendations, the simulator was implemented on hardware composed of an AMD Ryzen 5 3400G processor at 3.7 GHz, with integrated AMD Radeon Vega 11 graphics and 8 GB of RAM. The game runs in conjunction with OpenIV software, which is used by the modding community to implement new game modes or options not covered by Rockstar. This tool allows loading a modification (mod), developed by Killatomate called Realistic Driving V, to simulate various driving parameters such as technical details of cars, roads, and driving environments.

2.2. Methods

By default, the game does not provide tools to know the driver's performance or the values generated by the car during use. The video game has directional lighting support, although reserved only for the characters and not for the player, during their mobilization within the fictional city. So, an in-game mod was developed to extract the data and implement more realistic features in the player-controlled vehicle.

2.2.1. Game Data Acquisition

For the data acquisition, a script was created using the C# programming language and the Microsoft .NET framework [12]. The Grand Theft Auto V community has created libraries to add and enrich the game with new features. These libraries are ScriptHookV developed by Alexander Blade using the C programming language, and ScriptHookDotNet developed by Crosire using the .NET framework. Both tools focus primarily on allowing the user to develop game modifications by using scripts written in .NET that allow manipulation of game classes.

The video game modification allows for the collection of data on the drivers' actions during test drives. So it is necessary to define the vehicle's parameters to be collected as acceleration, speed, engine revolutions, steering wheel angle, clutch position, headlight status, turn signal status, collision detection, horn detection, and radio status. These variables can be obtained from the classes *GTA.Native* and *GTA.Math*, which contain, on the one hand, the data of the player's actions and, on the other hand, the actions made by other objects in the video game environment.

The next step consists of creating a new library that contains two classes: *iaMetrics* and *Metrics*. Moreover, this library inherited the public methods *Tick* and *KeyDown* of the *GTA.Script* class from the ScriptHookVDotNet library. These methods allow for the execution of instructions on each frame of the game and by pressing an assigned key, respectively. The *iaMetrics* class is created with public variables that monitor the storage of the values generated by the automobile. Meanwhile, the *Metrics* class contains the constructor method, called with the same name as the class. This method initializes the public variables and the public methods *onKeyDown* and *onTick*. In addition, it includes private methods, of which the most important are *Collector*, *getCoordinates*, *storePoints*, and *verifyAngle*.

The *Collector* method stores the car data in global variables; once verified that the player is inside a vehicle, the data are extracted using *GTA.classes*. This class contains the getter and setter methods that allow one to set and obtain the different variables. Instead, the method *onekey* oversees the activation of private methods such as *getCoordinates*, *storePoints*, *Dir Left*, and *Dir Right*. The first method stores the coordinates of the video game map inside a private variable of type list. The second method stores the coordinates in a plain text file, thus emptying the list created by the previous method. The last two methods supervise the activation of the blinkers and the parking lights by simulating the controls on the car dashboard. Furthermore, this project includes the control of the directional lights in the GTA.Native class. This option is normally enabled only for the characters in the video game. Also, the *verifyAngle* method was created to verify the use of the blinkers when the player turns in any direction.

Regarding the characters in the game, the mod doesn't make any modifications to their behavior so that the interaction with the user is as natural and realistic as possible. The video game includes characters with passive or aggressive behavior.

Finally, the sampling frequency was set to 60 Hz. This means that the mod captures the parameters of 60 frames every second, although there may be higher or lower peaks of frames depending on the graphic load of the game. The mod code and documentation are available at the following link: https://github.com/KuroGxbo/iaMetrics.

2.2.2. Route design

To define the routes, functions were designed using the *OnKeyDown* method, which activates the pre-established route within the game's GPS. For GPS activation, the *GTA.Native* class and the *Hash* function were used. The route was defined through a process of accumulating points by freely driving through the game. With the collected coordinates, three circuits were created: the first one crossing the city center, the second one through a suburb, and the third one passing through a highway. The *START_GPS_MULTI_ROUTE* method is used to draw and display the routes for the pedestrian, while the *SET_GPS_MULTI_ROUTE_RENDER* method displays the circuit on the map.

An important attribute to consider is the use of controls that provide greater immersion through controls made up of steering wheels, pedals, and even gear levers. Natively, Grand Theft Auto V does not provide support for this type of control but was incorporated into the proposed simulator. The game provides support for console controllers from Xbox and Play Station. To achieve this, the x360CE program was used, which allows the use of Xbox controllers compatible with Windows. For the tests, we used a Genius Steering Wheel model Twin Wheel F1 that includes acceleration and brake pedals. The default controls were used in the initial stages of development, but then some button assignments were changed to prevent the player from being distracted.

In addition, functions such as radio controls have been reassigned to other buttons so that the functions designed in the mod for turn signals and parking lights are assigned to the buttons on the steering wheel and used during the simulation.

2.2.3. *Evaluation of the tool*

For the evaluation of the simulator, a test scenario was set up with high-definition television, the pedals attached to the floor by means of a suction cup, and the steering wheel. The three previously defined circuits were used, referred to in a simplified way as the center, suburb, and highway.

In addition, to evaluate the simulator with reference to driving experience, a survey was designed with four sections and questions related to the information and perception of participants about the peripherals and the environment of the three circuits. The first section of the survey is related to the operation and instructions for operating the simulator and asks about the characteristics of the car, the peripherals and the types of circuit. In this section, player data, such as full names, are also collected; gender, Male (M) or Female (F); license type, Professional (PR) or Non-professional (NPR); and length of time held. Finally, it concludes by asking about their driving style, Passive (P) or Aggressive (A), and if the instructions given was clear.

Sections two, three, and four are answered after completing each circuit, and information is collected on the sensitivity of the controls and the closeness of the scenarios to reality. Interaction with other drivers and pedestrians, traffic signals, use of turn signals, parking lights, horn functions, and their usefulness during the test are included. Information about car data is also collected, such as the speed and sensitivity of the brake and accelerator pedals.

3. Results and Discussion

In the experiments, ten people with an age range between 26 and 58 years participated. Participants had different driving knowledge, that is, different types of official driving licenses, to have an objective opinion on their driving experience and interaction with the simulator. The Table 1 summarized the characteristics of the participant.

As shown in Figure 2, each person took three driving tests on three different circuits: downtown, highway, and suburbs. The main objective of each circuit is to expose the user to situations that would occur in real life while driving. For instance, in Figures 3(a) and 3(b), the interaction of the driver with traffic signals and pedestrians is shown, respectively. The average driving time in each circuit was 6, 7.7, and 5.8 minutes, correspondingly.

Table 1. Characteristics of the participants in the experiments.

Age	Type	Men		Female		Total
		A	P	A	P	
[20-30]	NPR	0	3	0	0	3
	PR	0	0	0	0	0
[31-40]	NPR	1	0	0	1	2
	PR	0	0	0	1	1
[41-60]	NPR	0	1	0	1	2
	PR	1	0	0	1	2
Total		2	4	0	4	10
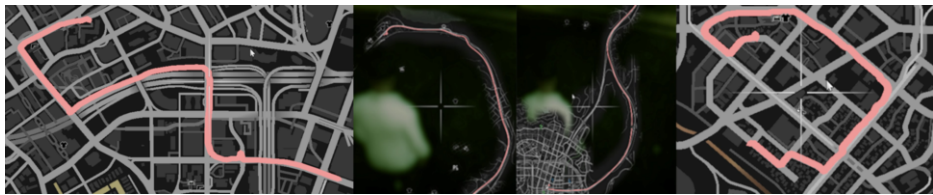
Figure 2. Downtown (left), freeway (center) and suburban (right) routes.

Once the driving test was completed, the participants conducted sections two, three, and four of the survey. These sections had 12 Likert scale questions dealing with ease of use of video game controls and perception of driving. The maximum weighting was 5 points and the minimum was 0.

Regarding the overall perception of the drivers' driving experience in the simulator, considering how real the driving test felt, i.e., the ease of use of controls, environment realism, and interaction with pedestrians and other cars, circuit 3 was rated the highest with 4.6 points, followed by circuit 2 with 4.4 points. The lowest rating, 3.9 points, was for the first circuit. Similarly, the feeling of realism was 4.2, 4.5, and 4.6 points for the first, second, and third circuits. Instead, the stress level caused by all tracks was less than 2.8 points.

On the other hand, the average ease of use of the controls of the three routes was 3.5, 4.5, and 4 points, respectively (see Figure 4). Thus, the most difficult route was the one that crossed the downtown city due to the interaction with the environment, especially traffic lights, pedestrians crossing, car acceleration and deceleration, etc.

(a) Interaction with drivers and traffic lights   (b) Interaction with pedestrians and traffic signals

Figure 3. Interactions of the driving simulator with the environment.
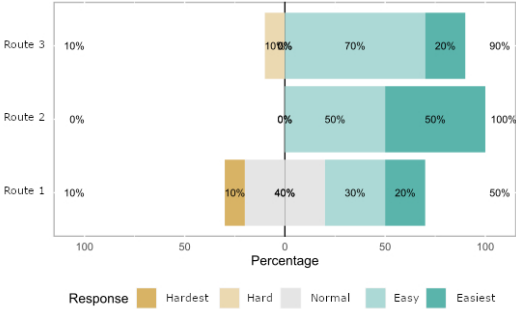
Figure 4. Results of the evaluation of ease of use in the controls of the car.

Concerning the use of the turn signals and parking lights in the three circuits, there was an appreciation with a rating greater than or equal to 4.5. In contrast, the throttle and brake controls were rated higher on routes 2 and 3, with average scores above 4.

During the tests, in a parallel and transparent way for the user, video game data on vehicle driving were obtained. A sample of the values collected is shown in Table 2. The data includes Boolean, real, integer, and time variables such as accelerator, collision, horn, revolutions per minute (rpm), turning angle (steerAng), frames per second (fps), date, etc.

Table 2. Sample data acquired with iaMetrics mod about vehicle parameters during the test drive.

Vehicle information								Lights state and game data								
accelerator	rpm	collision	clutch	steerAng	lights	highBeam	velocity	horn	rd	stateI	lockI	stateD	lockD	fps	date	hour
1	0.69	F	1	4	T	F	20.13	F	15	F	F	F	F	57	13/7/2021	14:47:14
1	0.7	F	1	4	T	F	20.52	F	15	F	F	F	F	51	13/7/2021	14:47:14
1	0.72	F	1	3	T	F	20.97	F	15	F	F	F	F	42	13/7/2021	14:47:14
1	0.74	F	1	2	T	F	21.3	F	15	F	F	F	F	56	13/7/2021	14:47:14
1	0.76	F	1	2	T	F	21.65	F	15	F	F	F	F	54	13/7/2021	14:47:14
1	0.78	F	1	2	T	F	22.06	F	15	F	F	F	F	49	13/7/2021	14:47:14
1	0.8	F	1	1	T	F	22.42	F	15	F	F	F	F	57	13/7/2021	14:47:14

It should be emphasized that the drivers, who were not feeling monitored, were able to act naturally. Therefore, the data collected reflects the behavior of drivers in an environment very similar to the real one. Each row in Table 2 shows the information stored by the collection method that runs in each frame of the game. The average sample rate was 55 fps.

4. Conclusion

In this work, we present the implementation of a driving simulator with adaptations of the Grand Theft Auto V video game. The combination of artificial intelligence and the graphics aspect of the game allows the driving experience to be perceived much more naturally. Likewise, thanks to the adaptations of the steering wheel and pedal controls, drivers were able to drive in virtual environments very close to reality, interacting with autonomous characters (drivers and pedestrians), who execute unpredictable actions, allowing the individual to face various scenarios in which we can collect data on your driving style. The modification made in C# using the .NET framework allows the data for driver behavior analysis to be collected in a way that is transparent to the user, en-

suring that the drivers' attitude is not somehow masked by knowing that they are being observed. In this way, in the future, a dataset can be generated with different attributes that could be used as input to machine learning models to determine the pattern of driver behavior.

5. ACKNOWLEDGMENTS

References

[1]   Groeger, J., Rothengatter J. Traffic psychology and behaviour. Transportation research part F: traffic psychology and behaviour 1.1 (1998): 1-9.
[2]   Pérez-Sánchez F., Bautista A., Salazar M., Macias A. Analysis of vehicular traffic flow using a macroscopic model. DYNA 81, 184 (2014), 36.
[3]   Sullman, M. Advances in traffic psychology. CRC Press, (2019).
[4]   Barjonet, P. Transport psychology in Europe: A general overview. Traffic and Transport Psychology. Theory and Application (1997).
[5]   Pekrun, R. Emotions and learning. Educational practices series 24.1 (2014): 1-31.
[6]   Revelle, W. Hans Eysenck: personality theorist. Personality and Individual Differences 103 (2016): 32-39.
[7]   Wang W., Xi J., Zhao D. Driving Style Analysis Using Primitive Driving Patterns With Bayesian Nonparametric Approaches. IEEE Trans. Intell. Transport. Syst. 20, 8 (2019), 2986–2998.
[8]   Eftekhari H., Ghatee M. Hybrid of discrete wavelet transform and adaptive neuro fuzzy inference system for overall driving behavior recognition. Transportation Research Part F: Traffic Psychology and Behaviour 58, (2018), 782–796.
[9]   Li G., Wang Y., Zhu F., Sui X., Wang N., Qu X., Green, P. Drivers' visual scanning behavior at signalized and unsignalized intersections: A naturalistic driving study in China. Journal of Safety Research 71, (2019), 219–229.
[10] De Winter J., Van Leeuwen, P., Happee, R. Advantages and disadvantages of driving simulators: A discussion. Proceedings of measuring behavior. Vol. (2012).
[11] Iqbal M., Sari K., Sekarwati K., Putri D. Developing PC-Based Driving Simulator System for Driver Behavior Analysis Research. In Journal of Physics: Conference Series, Vol. 1566, No. 1, IOP Publishing, (2020), p. 012075.
[12] Thai T., Lam H. .NET framework essentials. O'Reilly Media, Inc, (2013).

Gender Differences of Public Attitude to Government Guidance of COVID-19 Pandemic

Qingli MAN[a], Xinyu ZHANG[a], Guang YU[b] and Yongtian YU[c,1]

[a] *Zhiwei Data, Beijing, China 100010*
[b] *School of Management, Harbin Institute of Technology, Harbin, P. R. China.*
[c] *HSBC Business School, Peking University, Shenzhen, P. R. China. 518055*

Abstract When a major public health incident breaks out, in order to prevent the explosion of multiple types of public opinion, relevant government departments need to guide the online public opinion according to the needs and characteristics of different audiences in order to achieve reasonable regulation and control. In this process, gender differences among the participating public in areas such as comprehension ability often affect the effectiveness of government guidance. A proper understanding of these differences will enable the government to allocate resources on the basis of needs to save resources and achieve the same goals with half the effort. This paper takes the outbreak of the COVID-19 as an example to analyze the gender differences among users in terms of the overall volume of participation and specific participation behaviors from the dimension of time and geographical locations. A total of 735,271 comments posted by users in responding to tweets published by 144 official government accounts on Weibo during the COVID-19 outbreak were collected and analyzed with a combination of the methods of natural language processing and propensity score analysis. The results show that in comparison to male users, female users participated more, and their responses were more emotionally expressive. Female users tended to respond faster than male users by 30 minutes to an hour, which allowed female users to play a more important role in the process of government guidance of public opinion during major public health incidents. Therefore, this study further provides policy recommendations for the government to provide reasonable guidance of public opinion and give future direction.

Keywords. Gender differences; government guidance of public opinion; natural language processing; propensity score matching; life cycle of public opinion; geographical analysis

1. Introduction

When a major public health incident breaks out, the government tends to actively guide public opinion in order to prevent the accumulation of multiple types of online public opinion from affecting the stability of the society. From the perspective of crisis management and communications, reasonable guidance of public opinion needs to be carried out in accordance with the characteristics of different audiences and situations

---

[1] Corresponding Author, Yongtian YU, HSBC Business School, Peking University, Shenzhen, P. R. China; E-mail: yongtian@zhiweidata.com.

[1]. As the audiences of government guidance, the public respond to government measures and actively participate in the interaction with the government, thus further forming and spreading public opinion. When guiding public opinion, the government needs to consider the objective differences among the audiences, take account of the needs of the audiences and design better response strategies in accordance with the actual situation in order to achieve better effects in guiding public opinion. Gender differences are the biggest differences among the audiences.

Different scholars have set foot in this field and try to mine the gender differences in participating in social media. They focused on the gender difference in social media participation to mine the willingness [2], expressing emotions[3], and expressions[4]. Some scholars also studied the gender differences around different types of events. Political affairs [5], political election [6], disasters[7], rumors disseminations [8] have been researched. These studies have mined the different gender differences and gender differences character on different platforms and scenarios. They affirm the gender differences in various behaviors of social media usage, and also point out the gender differences in participating in public opinion generated around different types of events.

However, it should be noted that although studies have explored gender differences in participating in the dissemination of public opinion generated around various types of events, few studies have focused on gender differences in the participation in public opinion generated around major public health incidents. There is an obvious gap in the research on the gender differences in participating in the process of government guidance of public opinion under major public health incidents.

Public opinion resulting from this type of events differs in many ways from the cases examined in previous studies. First, major public health incidents last for a long duration, and there is a clear event life cycle. Unlike previous studies of homeostatic environments under normal conditions, this type of events can be divided into different stages, and it is still unknown whether gender differences in participation will display different characteristics in the different stages. Secondly, in an environment of nationwide participation, there are obvious geographical characteristics in the dissemination of public opinion, and under the influence of such geographical characteristics, there may be gender differences in the process of public opinion dissemination. In consideration of both event life cycle and geographical locations, the questions of whether and what kind of gender differences in participation exist when the government provide guidance during major health public incidents still remain a gap in current research and examining these questions can be very useful for the government to guide public opinion according to the needs of the actual situation.

Given the above issues, this paper takes the COVID-19 pandemic as an example to investigate gender differences in public participation in the process of governmental guidance of online opinion under major public health incidents. The outbreak of the COVID-19 pandemic in early 2020 was the most serious major public health incident in recent years. Also, opinions on social media have reached an unprecedented volume. Various hot topics continued to emerge online, various incidents continued to ferment online, and multiple types of information continued to spread on social media. The complex and massive spread of opinions on the social media poses a challenge for governments to give adequate responses. Taking China as an example, Figure 1 below shows the number of Weibo tweets posted by the official social media accounts of provincial governments during January 15-19, January 20-24, and January 25-29, as well as the number of COVID-19-related tweets posted. It can be seen that all local

governments have substantially stepped up its measures of guidance in relation to COVID-19 during the pandemic.
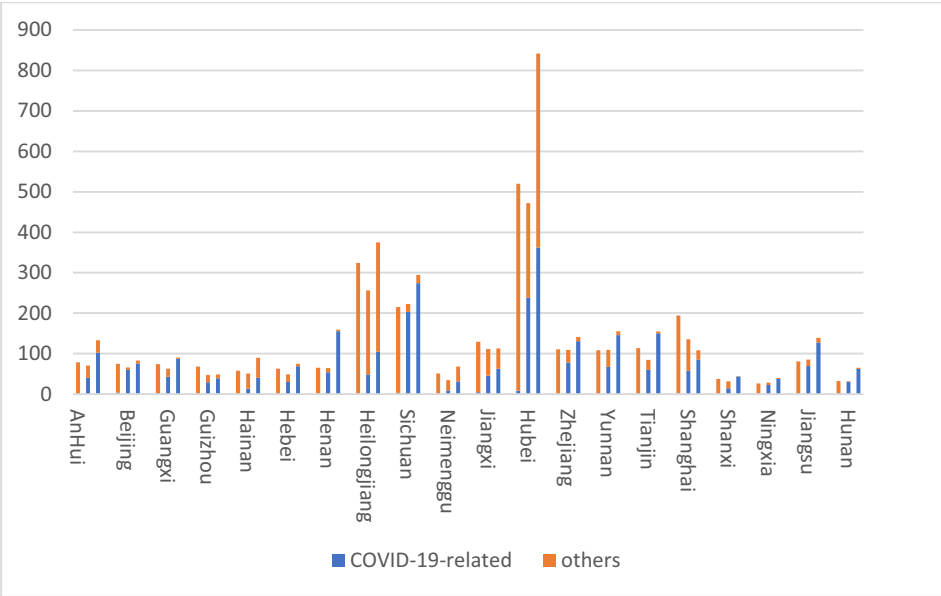
Figure 1. The number of COVID-19-related and non-COVID-19-related tweets posted by local governments during January 15-19, January 20-24, and January 25-29

As the content of these official tweets was highly related to governmental guidance, the dissemination of public opinion they elicited provide an opportunity to explore gender differences in participating in the dissemination of government guidance of public opinion under major public health incidents.

Therefore, this study tries to mine the gender difference of public attitude to government guidance of major public health incidents. Taking COVID-19 pandemic as an example, based on the Weibo tweets about the pandemic posted by 144 Chinese official media accounts of 34 local governments and 735,271 comments from ordinary users on Weibo from January 15, 2020, to March 3, 2020, we conducted this research. Also, this study used the methods of natural language processing and propensity score analysis to analyzes the gender differences in the overall participation. The results point out the gender differences in participation in different time periods and different geographical locations. Besides, the study analyzes the gender differences in specific participation behaviors and concludes that female users participated faster than male users and that female responses were more emotional.

Combining these two findings, this study confirms the gender differences in participating in the process of government guidance of public opinion, as well as the dominant role of female users in the process.

2. Related word

2.1. Gender differences in social media participation

Guided by the idea that public opinion management needs to be addressed according to the needs of the actual situation, more and more scholars have paid attention to the issue of gender differences in participating in social media. Research has also confirmed that there are indeed gender differences when it comes to social media participation. Existent studies cover different types of participant behaviors. Earlier researchers focused on the information amount. Such as Kleman studied the amount of information expressed by male users and female users[9], and tried to explain the differences of participation behaviors between the two types of users. Elm studied emotion expressed by male users and female users on social media and found that female users are more inclined to express emotions and discuss interpersonal relationships on social media, are more interested in communicating and tend to express t[3]themselves in an emotional way. The similar result is also in Tong's research. In her research, she found while male users are more direct in their expressions[4]. Zhang et al studied the gender emotional differences in Web forum communication, the analysis results indicate that women are more likely to express their opinions subjectively than men (based on sentence-level analysis), and they are more likely to express both positive and negative emotions (based on phrase-level and word-level analyses)[10].

Similar to this research, recent studies focused on the willingness of male users and female users to participate in social media-based discussions[2], and the significant differences in what and how they express. Recent studies also contained the study in instagram hashtag use. Ye et al[11] studied gender differences in instagram hashtag use and found that compared to male users, female users tend to use emotional and positive hashtag descriptions.

2.2. Gender differences in different scenarios

While these studies affirm that there are gender differences in social media participation, they also point out that there are gender differences in the participation in the dissemination of public opinion generated around different types of scenarios. For example, for political affairs, male users and female users still maintain the social norms formed in traditional offline settings even in participating in social media. Xue et al studies the gender differences in political news and found female users discuss and follow political news less than men[5]. Zhang studied the enthusiasm for participation and found that females participate in events such as political election less enthusiastically than male users[6]. For interactive events such as online political discussions, however, female users display more enthusiasm in participation [12]. Similarly, female users are more enthusiastic about spreading rumors than men, while male users are more enthusiastic about reporting rumors [8].

Except for the political scene, scholars also studied some other scenarios. Li et al studied the gender differences on social media when disaster happened[7]. Liu and Li studied the gender differences in online health communities. The results indicated that male users' posting content was usually more professional and included more medical terms, female users were more inclined to seek emotional support in the health communities. Female users expressed more negative emotions than male users did,

especially anxiety and sadness. In addition, male users were more centered and influential in the friendship network than were women[13].

These researches mined the gender differences on social media platforms and different scenarios. They analyzed the different types of gender differences and laid a solid foundation for subsequent research. But they haven't get involved in government management. This scenario has its unique features, such as the gender differences of participation are under the government guidance.

Gender differences in the ability to understand the information released by the government, the attitudes toward the government, and the willingness to participate in the dissemination of public opinion hugely influence the effectiveness of government guidance of public opinion during the pandemic. For this reason, an in-depth analysis of the gender differences in participating in the process of government guidance of public opinion sheds significant insights on how the government should control public opinion according to the needs of the audiences and make reasonable decisions in formulating future policies and strategies.

And also, we focused on the government guidance of COVID-19, this unique pandemic has its different character. And this study will focus on it and mine the gender difference on public attitude to the government guidance of this COVID-19. And show a different direction on the government management of emergency incidents

3. Method

3.1. Data collection

In this paper, the social media platform Weibo was chosen to collect data for the study. In recent years, Weibo has become more and more important worldwide, and its functions were gradually developed as the sum of Facebook and Twitter[14]. We acquired data from Weibo using the data acquisition framework developed by Zhiwei Data. Zhiwei Data is a top Internet intelligence service company in China and has been providing real-time monitoring of public opinion and information on the Internet as well as analysis and early warning services for enterprises and government agencies for a long time. Based on the methods of API and web crawler in data acquisition, we obtained tweets posted by 34 official Weibo accounts of provincial and municipal governments and government media from January 15, 2020, to March 6, 2020. Tweets of a total of 144 accounts in 34 provinces and municipalities were collected. We worked with Zhiwei technicians to manually filter out government tweets that were not related to the pandemic during this period and used rest to represent the tweets posted by 34 provinces and municipalities in relation to government guidance of public opinion.

Second, we started to collect comments on Weibo in response to these tweets on March 20, 2020, and the comments from January 15 to March 6 were collected. Finally, we only kept the data acquired from commenters labelled as "ordinary users" on Weibo and used this data to represent public participation in the process of government-guided dissemination of public opinion. We conducted computational analysis based on this data.

3.2. Variables and measurements

The variables included in this study are divided into two groups. One group contains the variables based on the data about tweets and comments directly obtained, and the other group contains variables based on the data calculated from the raw data.

3.2.1 Variables obtained directly

Among them, variables based on data directly obtained are:

(1) Number of fans of users (fan_num): referring to the number of fans of users who made comments under the official government tweets.

(2) Number of followers of users (fol_num): referring to the number of followers of users who made comments under the official government tweet.

(3) Number of tweets posted by users (weibo_num): referring to the number of tweets posted by users who made comments under official government tweets.

(4) Gender of the user (gender): referring to the gender of the user who made comments under the official government tweet. Male users were coded as 1 and female users were coded as 0.

(5) Region of users (region): representing the geographical distribution of users who made comments under the official government tweet in the 34 provinces, autonomous regions, and municipalities.

(6) User's reply time (rep_time): referring to the specific time when the user replied to the official government tweet.

(7) User's reply moment (time): referring to the exact moment when the user replied to the official government tweet.

(8) The posting time of the government-posted tweet commented by the user (weibo_time): the posting time of the original tweet which was commented by the user.

3.2.2 Variables obtained by calculation

The variables based on data obtained by calculation in this study include:

(1) The speed of users in making comments to tweets published by governments (rep_speed): calculated by the difference between the reply time of the user and the posting time of the government-posted tweet, i.e.

$$rep\_speed = rep\_time - weibo\_time \qquad (1)$$

(2) The word count of user's comment on government-posted tweet (words_num): counting the number of words of user's comment. It is worth mentioning that this study explores the complexity of users' comments on government-posted tweets using the word count of the comments. Therefore, when calculating the word count, we retained punctuation, emoji, and other elements that would normally be removed through data denoising in order to achieve a better representation of the complexity of the comments.

(3) Vector of user's comment on government-posted tweet (text_vec): In order to better calculate linguistic features of users expressed in the comments posted by users to analyze the psychological characteristics of users, this study used the Skip-gram model in Mikolov 's article on word2vec[15, 16]to transform the content of the comment into computable text vectors. The goal of the Skip-gram model is to find the set of parameters θ to maximize the product of the conditional probabilities in the following equation:

$$\arg \max_{\theta} \prod_{\omega \in Text}\left[\prod_{c \in C(w)} p(c|w; \theta)\right] \qquad (2)$$

where w (word) refers to the words in the text, represented by a column vector of length d; T (Text) is the overall set of the content of the text; θ denotes the model

parameters; context (context) denotes the words contained in a phrase formed by moving k words forward and k words backward, with word w as the center; conditional probability $P(c|w)$ is the probability that a certain context c occurs when w occurs; $C(w)$ denotes the set of words contained in the context in which word w has appeared in the overall set T; c is the words in the context, denoted by a column vector of length d, c $\in C(w)$. While both c and w denote words, Mikolov argues that even for the same word, e.g., apple, its vectors as a common word and as a word in context are different, so different symbols are used to represent words in context and common words.

Equation (2) can be equated to the following equation:

$$\arg \max_{\theta} \prod_{(w,c)\in D} p(c|w; \theta) \tag{3}$$

where D is the set consisting of the word w and its context $C(w)$.

On the basis of Equation (3), the conditional probabilities can be transformed and expressed by the following equation using softmax:

$$p(c|w; \theta) = \frac{e^{v_c \cdot v_w}}{\sum_{c' \in C} e^{v_{c'} \cdot v_w}} \tag{4}$$

where, v_c and v_w are column vector of c and w with dimension d; C is the set consisting of all words in the context, which is equivalent to the vocabulary V corresponding to the set of texts.

Thus, in this equation, parameter Θ is the specific value taken for each dimension in v_c and v_w, and the total number of parameters is $|C| \times |V| \times d$. Taking the logarithm of the above equation on both sides yields

$$\arg \max_{\theta} \sum_{(w,c)\in D} \log P(c|w) = \sum_{(w,c)\in D} (\log e^{v_c \cdot v_w} - \log \sum_{c'} e^{v_{c'} \cdot v_w}) \tag{5}$$

The core idea of using the Skip-gram model to transform texts into vectors is that there is an underlying assumption that similar words have similar contexts and that a particular context can only be matched by a certain semantic connotation. Therefore, by maximizing the conditional probability, the correspondence between words and contexts will be the closest and maximized. And the vector of a word that satisfies the maximum conditional probability serves as a reasonable representation of the semantics of the word.

Therefore, we used the Skip-gram method in word2vec [15] to represent the emotional characteristics of the pre-processed text and convert the textual form into numerical form. Word2vec was developed by Google and became open source in 2013, with many relevant toolkits in python. This paper conducted research by using the gensim toolkit in python. This study used this method to transform the comments into numerical characteristics vectors containing semantic information. Finally, by weighted summation, we calculated the vector representation of each comment.

3.3. Research methods

3.3.1 Overall Participation Method

We first analyzed the gender differences in overall participation using comments in response to government-posted tweets based on the data retrieved. We analyze and discuss the overall differences from the temporal and geographical dimensions.

In the temporal dimension, we counted the comments by both male users and female users replying to government-posted tweets and relevant data from January 15, 2020, to March 6, 2020, and used the method of visualization to reflect the gender differences in participation. Also, in this paper, we selected six special time points as a way to divide this period of the COVID-19 pandemic into several stages. These six time points were: on January 24, the cumulative number of confirmed cases in China exceeded 1,000 for

the first time and reached 1,287; on January 31, the cumulative number of confirmed cases in China exceeded 10,000 for the first time and reached 11,821; on February 5, the peak, or inflection point, was reached, with the daily number of confirmed cases in China being 3,694; on February 12, China upgraded the testing method of new cases and the daily number of confirmed cases was 15,152; on February 19, the daily number of new cases in China dropped back to below 1,000, at 820; on March 6, the daily number of new cases in China dropped to below 100, at 99.

In the geographic dimension, we conducted geostatistical analysis to examine the gender differences in participation. Geostatistics, also known as spatial statistics, is a method to summarize the number and types of geographical elements in a certain area to reflect the spatial distribution of geographical elements[17]. In combination with frequency and other measurements in statistics, it calculates and displays the values of the corresponding attributes at each location in space, so as to discover the correlation between the attributes, as well as the patterns of spatial distribution of things and their underlying causes. We counted the geographic distribution of males and females participating in discussions in the 34 provinces and municipalities and drew a map of public participation under the tweets posted by the official accounts of the 34 provincial and municipal governments using the method of visualization to show the gender differences in participation.

3.3.2 Gender differences Method

We analyzed the differences in male and female users' participation behaviors by examining the differences in the content, speed, and complexity of male and female users' comments on government-posted tweets.

In the content dimension, we performed tokenization and counted word frequency of the comments obtained from male and female users. Drawing on the wordcloud visualization method, we generated word clouds and high-frequency word charts of male and female users' content of participation, so as to more visually show the topics and contents that users were more concerned about in their comments on government-posted tweets during the pandemic. Based on this, we analyzed the gender differences in linguistic characteristics and other dimensions.

When analyzing the differences in speed and complexity between male and female users' participation behaviors, the speed and complexity of the comments by each user cannot be simply summed up as in the analysis of overall difference. When we calculated the overall quantitative values of male and female participation, the quantitative value of a single comment could be uniformly considered as 1, so it was valid to do a summation. However, in the analysis of behavioral differences, the differences in speed and complexity of the comments were different and could not be simply summed up. Moreover, the difference in the speed of the comments was also influenced by the users' geographical locations, the psychological features of the users represented by the linguistic characteristics, and the users' basic attributes. Simple summation could constrain the results of the analysis of the gender differences in participation behaviors. Therefore, to address this problem, we drew on the method of Propensity Score Matching (PSM) [18] in the analysis. The Propensity Score (PS), in combination with matching, was calculated by comparing the characteristic behaviors of male and female users who were otherwise similar to represent gender differences in behaviors with the Average Treatment effect for the Treatment (ATT). The steps are summarized as follows:

Firstly, we calculated the Propensity Score. The Propensity Score is the conditional probability of accepting a member of the treatment group given the preprocessing characteristics [18]. It can be expressed as.

$$p(X) = \Pr[D = 1|X] = E[D|X] \tag{6}$$

where, X denotes a multidimensional vector representing the characteristics of the control group; D denotes the indicator variable, 1 for male and 0 for female.

Drawing on previous studies [19, 20], we used the Logit model to calculate the Propensity Scores. We estimated probability using the Logit model:

$$p(X_i) = \Pr[D_i = 1|X_i] = \frac{e^{\beta X_i}}{1+e^{\beta X_i}} \tag{7}$$

where X denotes the multiple features of the independent variable that can be used as a basis for determining whether a user is male or female. β indicates the coefficient of the feature. The Propensity Score, on the other hand, is the estimation of the Logit model.

Secondly, we used the method of matching to match similar users. In this study, we use the nearest neighbor matching method, i.e., search for the closest similarity in the Propensity Scores from the stimulus group by moving forward and backward and use it as a control sample, i.e.

$$C(i) = \min_{j}\|p_i - p_j\| \tag{8}$$

$C(i)$ indicates the control unit matching the i stimulus unit; p_i and p_j indicate the Propensity Scores of the stimulus and control groups, respectively.

Finally, the differences between the two groups were calculated by calculating ATT.

$$ATT = E[Y_{1i} - Y_{0i}|D_i = 1] = E\{E[Y_{1i}|D_i = 1, p(X_i)] - E[Y_{0i}|D_i = 0, p(X_i)]|D_i = 1\} \tag{9}$$

where Y_{1i} and Y_{0i} denote the potential output values of the stimulus and control groups, respectively, which are the behavioral variables in this study.

In this study, we adopted the temporal division of multiple stages to explore the differences in participation behaviors throughout pandemic and under different stages of development of the pandemic, respectively.

4. Results

Building on the above experimental methods, we obtained tweets posted by a total of 144 official Weibo accounts of 34 provincial and municipal governments and government media from January 15, 2020, to March 6, 2020, and collected a total of 735,271 comments replying to these tweets. We sorted out the content of these comments and information about the commenters to conduct subsequent analysis.

4.1. Analysis of gender differences in overall participation

We counted the daily volume of users' comments from January 15 to March 6, summarized in Figure 2 below.

As can be clearly seen from Figure 2, during the pandemic, female users accounted for the vast majority of the group involved in the discussions of government-posted tweets. Compared to the volume of comments by male users, the volume of comments by female users was larger and built up quickly. However, in terms of overall chronological trends, the trends in comments by male and female users were largely consistent. When broken down into the various stages of the pandemic, it can be seen

that during the relative severe periods of the pandemic, i.e., from the beginning of the outbreak to February 19 when the daily number of confirmed cases of COVID-19 fell back to less than 1,000, female users were more active in the discussions than male users. When the regulation and control measures of the pandemic were stabilizing and the pandemic was coming to an end, female users were as active in the discussions as male users were.
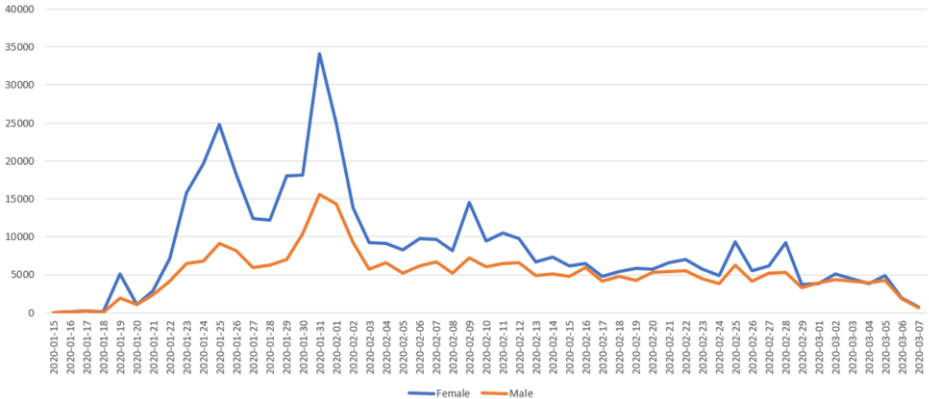
Figure 2. Chronological distribution of male users' and female users' daily volume of comments

Using the methods described above, we counted the volume of male and female participation in discussions and the proportion of male to female participation in discussions in the 34 provinces and municipalities at the six time points of January 24, January 31, February 5, February 12, February 19, and March 6, and combined the results with geographical analysis to examine the gender differences in participating in discussions in each province and municipality. We plotted the geographical distribution of comments in the 34 provinces and municipalities in Figure 3 below, using female users' comments as an example.

In the figure 3, the left side of the graphs for each single day indicates the volume of female users' participation in the discussion of government-posted tweets in different geographic locations, and the right side indicates the percentage of female users' participation in the discussion. The darker the color, the larger the volume and the proportion. In contrast, the lighter the color, the smaller the volume and the proportion. Among them, the overall volume of participation in the discussions in some cities on March 6 was very small (e.g., in Qinghai and Inner Mongolia), so the results depicted in the graphs for these cities were subject to errors. As a whole, the changes on the left side of the single-day graphs echo the conclusion of Figure 1 that the amount of female participation in the discussion changed along the course of the pandemic. At the same time, we can further see that the changes in female participation in the discussions were mainly concentrated in the coastal areas. Moreover, the changes in the percentage of female participation in the discussions can be clearly seen from the right side of the single-day graphs. When the pandemic was severe, among those involved in the discussions of the government-posted tweets, the majority were female users. Especially in the early periods of the pandemic, the population involved in interacting with the government in all regions of the country were predominantly female. And as the severity of the pandemic decreased, female participation in discussions faded away and gradually became equal to male participation. At the same time, in terms of geographical distribution, in both areas where the pandemic remained severe and coastal areas, the

percentage of female participation in the discussions remained relatively higher and went down slower.
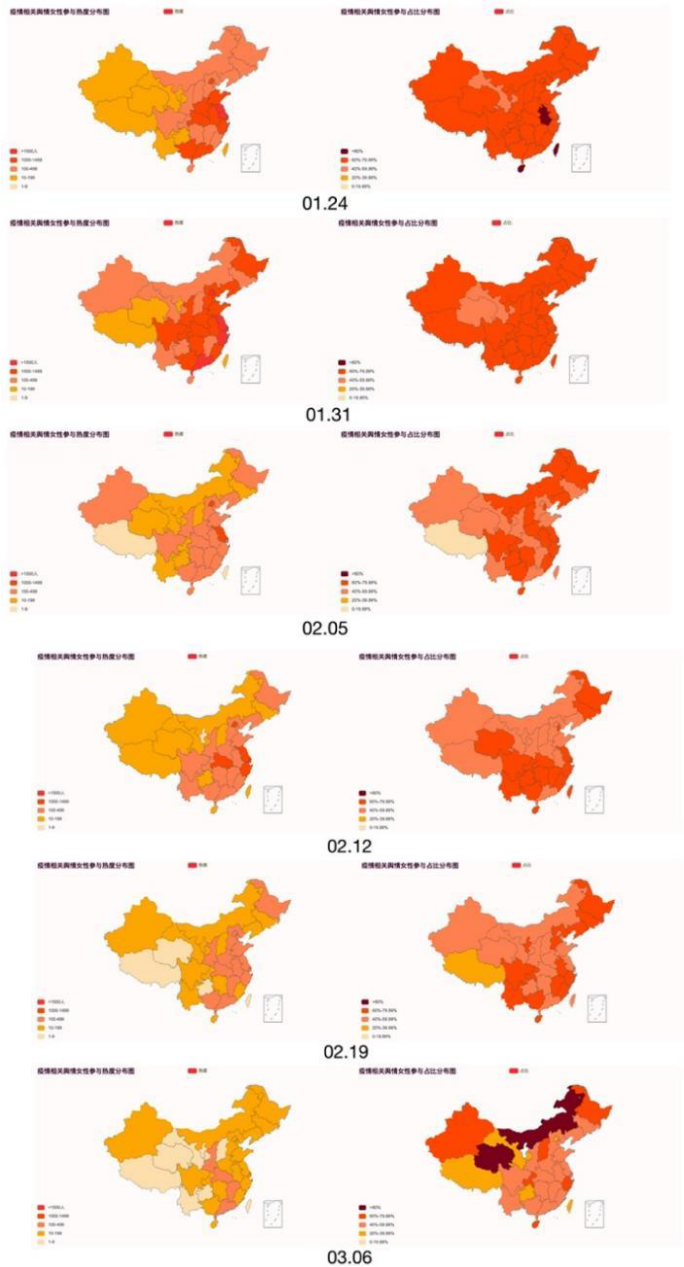
Figure 3. Volume of female participation in the discussions and its distribution in the 34 provinces, and municipalities

4.2. Analysis of gender differences in participation behaviors

4.2.1 Comparison of the content of the comments posted by male and female users

We sorted out the content of the comments posted by male and female users in response to government-posted tweets between January 15, 2020, and March 6, 2020, and analyzed them by tokenization, counting word frequencies and drawing word clouds. The results are shown in Figure 4 below:

Figure 4. Word clouds of the content of the comments posted by male and female users

As we mentioned in the Methods section, we did not denoise the comments in order to preserve as much information as possible about the linguistic and psychological characteristics of the users. In the figure 4 above, the font size is larger for the more frequent words and smaller for the less frequent ones. The two figures above allow us to explore both gender differences in the content of comments and in the way of commenting. From the two graphs, we first find that female users' comments contained more emotions than male users' comments. In female users' comments, there were more emoji such as "sad" and "candle" and more emotional words such as "cheer up" than in male users' comments. At the same time, female users expressed more specific details, such as "level 1" and "response" than male users. This reflects the fact that female users addressed policy details more often in their comments, while male users did not. Not only was there a difference in content, but there was also a difference in the way male users and female users participated in commenting government-posted tweets. Among them, male users were more likely to reply to others, thus the frequency of "replies" was much higher than that of female users. In contrast, female users were more likely to post their own comments directly.

4.2.2 Calculation of the Propensity Score for male and female users

We calculated the Propensity Score of the users with the method of propensity score calculation and moved to appropriate variables for the subsequent propensity score analysis. The descriptive analysis of the variables as a whole is shown in Table 1 below. The text vector (text_vec) is not listed in the table because it was generated with the word2vec method.

Table 1. Descriptive analysis of variables

Variable	Mean	Std.	Min	Max
words_num	15.375	15.092	2.000	318.000
rep_speed	11.717	37.044	0.014	1480.478
fan_num	757.406	21140.460	0.000	4270510.000
weibo_num	1379.274	5666.282	0.000	512445.000
fol_num	307.002	456.255	0.000	20000.000

Based on the analysis of normality, we took the logarithms and analyzed the variables words_num, rep_speed, fan_num, weibo_num, and fol_num respectively. We used gender as the dependent variable, and based on previous studies, we first conducted analysis with the Logit model using the three variables fan_num, weibo_num, and fol_num in Model 1. Second, in conjunction with the analysis of the overall gender differences from the geographic dimension in Section 3.1, we included the geographic variable region in Model 2. Finally, in conjunction with the analysis of gender differences in the content of comments in Section 3.1, we added the linguistic text vector text_vec in Model 3. The results are shown in Table 2 below. Among them, the region variable contained the categorical variables of 34 provinces and municipalities in China, while the linguistic text vector (text_vec) was added as a 10-dimensional text vector.

Table 2. Estimation of the Logit model

	Model 1	Model 2	Model 3
fan_num	0.124***	0.135***	0.133***
	(66.85)	(71.38)	(69.12)
weibo_num	-0.147***	-0.149***	-0.149***
	(-101.18)	(-101.87)	(-100.18)
fol_num	-0.134***	-0.131***	-0.125***
	(-49.90)	(-48.69)	(-45.48)
region		✓	✓
text_vec			✓
_cons	0.373***	0.279***	1.258***
	(32.82)	(17.24)	(55.08)
Pseudo $- R^2$	0.019	0.025	0.049
N	735271	735271	735271

* p<0.1 ** p<0.05 *** p<0.01

We sorted out the results of estimation in Table 2. From the results of the experiments, it can be seen that the probability of whether users participating in the discussions of government-posted tweets can be identified as male or female was positively correlated with the number of fans of users, and negatively correlated with the number of tweets and followers of users. And the results of Model 2 after considering the geographical information and Model 3 after considering the linguistic information showed a significant increasing trend in Pseudo $- R^2$. Since our goal is to find the appropriate model to estimate the Propensity Score, and from the results, Pseudo $- R^2$ of Model 3 had the best results, we chose Model 3 as the model to estimate PS and proceeded to the next step of calculation.

4.2.3 Matching of male and female samples

With the method of nearest neighbor matching introduced in Section 2.3.2, Figure 5 shows the kernel density plots for the stimulus and control groups before matching as well as after matching. As can be seen from the figure 5, although the overall distribution of the stimulus and control groups before matching was relatively similar, their overlap was relatively large. Given the large experimental sample, the results of comparison directly before matching could be biased. And in the plots after matching, we can see from the right side of Figure 5 that the kernel density plots of the two groups had significantly more overlap. This means that in the two selected samples after matching, both were more similar in each characteristic, indicating more convincing results.

Figure 5. Kernel density plots before and after sample matching

4.2.4 Results of analysis of gender differences in behaviors

We first calculated the ATT for the speed and complexity of comments of male and female users during the pandemic. To illustrate the gender differences in participation behaviors across different time periods, we divided the pandemic outbreak into several stages based on the six special time points. The first stage is January 15-January 24, indicating the stage from the beginning of the pandemic to the gradual rise of cases; the second stage is January 24-January 31, indicating the stage of complete outbreak; the third stage is January 31-February 5, indicating the stage of the pandemic with the case number remaining at a high point; the fourth stage is February 6-February 12, indicating the turn of the pandemic and the existence of special circumstances in the process; the fifth stage is February 12-February 19, indicating the decline of the pandemic; the sixth stage is February 19-March 6, indicating the gradual ending of the pandemic. The overall results divided by stages are shown in Table 3 below.

Table 3. Overall and stage-specific gender differences in participation behaviors

BM: Before Matching

AM: After Matching

Varible	Sample	Stimulation group	Control group	ATT	s.e.	t-value
Stage I						
rep_speed	BM	5.30	5.64	-0.34	0.93	-3.64***
	AM	5.30	6.21	-0.90	0.14	-6.37***
words_num	BM	15.47	17.07	-1.61	0.13	-12.25***
	AM	15.47	17.10	-1.63	0.19	-8.56***
Stage II						
rep_speed	BM	8.93	8.50	0.42	0.08	5.04***
	AM	8.93	9.28	-0.35	0.13	-2.79***
words_num	BM	15.28	15.87	-0.59	0.07	-7.96***
	AM	15.28	16.04	-0.75	0.11	-7.07***
Stage III						

rep_speed	BM	14.76	14.66	0.10	0.19	-0.50
	AM	14.76	15.93	-1.17	0.28	-4.22***
words_num	BM	14.83	14.67	0.16	0.09	1.75*
	AM	14.83	15.03	-0.20	0.13	-1.49
Stage IV						
rep_speed	BM	12.49	12.12	0.36	0.22	1.64
	AM	12.49	12.65	-0.17	0.33	-0.52
words_num	BM	15.20	15.06	0.14	0.09	-1.58
	AM	15.20	15.55	-0.35	0.13	-2.68***
Stage V						
rep_speed	BM	12.29	12.28	0.01	0.30	0.04
	AM	12.29	13.58	-1.29	0.45	-2.84***
words_num	BM	15.35	15.40	-0.05	0.11	-0.44
	AM	15.35	15.77	-0.42	0.16	-2.53**
Stage VI						
rep_speed	BM	12.70	13.37	-0.66	0.26	-2.57**
	AM	12.70	13.94	-1.23	0.38	-3.22***
words_num	BM	14.89	15.15	-0.25	0.08	-3.25***
	AM	14.89	15.59	-0.69	0.12	-6.03***
Total						
rep_speed	BM	11.44	10.91	0.53	0.08	6.35***
	AM	11.44	11.92	-0.48	0.13	-3.76***
words_num	BM	15.13	15.52	-0.40	0.37	-10.82***
	AM	15.13	15.74	-0.61	0.55	-11.06***

* p<0.1 ** p<0.05 *** p<0.01

From Table 3, we can first see that the results before matching and after matching were somewhat different, especially in the variable reply speed. From the results, it can also be found that at multiple stages, the results before and after matching were opposite. This also indirectly proves the importance of matching.

Second, for the gender difference in reply complexity (words_num), in terms of both overall results and results of each stage of the pandemic, although there was a statistical difference between male users and female users, the difference was small, with a maximum value of only 1.634, i.e., the difference in the word count of male users' and female users' comments on government-posted tweets was the largest in the first stage, at 1.634. This was small relative to the overall word count of comments, and the results can be summarized as essentially no difference in the reply complexity between male and female users.

Third, the results in Table 3 show that there was a large difference in reply speed between male and female users. As a whole, female users replied 0.479 hours faster than male users. And when we look at each stage, female users responded faster than male users in all stages, except for stage 4, where there was no statistical difference in the reply speed between male and female users. Furthermore, except for the relatively small difference in the second stage (0.352 hours), female users replied about one hour faster in all other stages in comparison to male users.

5. Conclusions, recommendations and future studies

This paper analyzes and digs into the gender differences in participating in government guidance of public opinion under major public health incidents, taking the COVID-19 pandemic in early 2020 as an example. By taking together the results of the analysis of the gender differences in overall participation in the process of government guidance of public opinion during pandemic and the results of the analysis of the differences in

specific participation behaviors, we can conclude that there were gender differences in the process of participation.

More specifically, firstly, female users were more active than male users in participating in the process of government guidance of public opinion. In terms of overall participation, female users' volume of participation was higher than that of male users. In terms of the reply speed, female users were also faster than male users. This finding is in line with existing research that female users are more likely to engage in social media related activities[9], but does not agree with the argument that male users are less likely to be politically active on social media platforms organized around weak ties such as Weibo [5]. In a sense, government guidance of public opinion during a major pandemic belongs to a special category of political activity. The content is no longer irrelevant to the general public but is instead highly relevant to their daily lives. In this bigger scenario, female users show a higher level of enthusiasm in participating in activities like government guidance of public opinion than male users. This result supplements the existing studies related to the gender differences in social media participation.

Second, differences in male and female users' enthusiasm to participate change as major public health incidents unfold. When the COVID-19 pandemic was in the stage of outbreak, female users were more enthusiastic than male users in participating. When the pandemic was gradually brought under control, female users' participation declined to a larger extent than male users. This suggests that female users' enthusiasm for information and engagement rises and falls quickly, and that they are more likely to feel exhausted by information overdose[21]. In contrast, when the pandemic is in a state of constant change (e.g., the daily case number changing from breaking 1,000 to breaking 10,000, change in the testing method after passing the inflection point), the gender difference in the reply speed was smaller than the difference when the pandemic was in a relatively stable state (e.g., the daily case number staying at a peak or going downward). To some extent, this shows that male users are more thoughtful in judging the accuracy of information.

Third, in China, gender differences in participation are also characterized by geographical differences and differences in content. Among them, in coastal cities, the extent to which female users were more enthusiastic than male users was larger than that in inland cities. Although there was little difference in the complexity of the content expressed by male and female users, there was a difference in the emotions expressed in the content, with female users more willing to express emotions, and this is consistent with the findings of existing research[3].

This study not only complements the findings of studies related to gender differences in participation in social media, but also reveals phenomena that provide important implications for the government to guide public opinion under major public health incidents.

First, the government needs to take into account the differences between male and female users when guiding public opinion. The government cannot expect one single tweet posted on its official Weibo account to achieve complete guidance of public opinion but needs to adopt specific measures (such as replies, celebrity endorsement, etc.) for a secondary or multiple round of guidance. In this process, gender differences among the audiences need to be taken into account as much as possible to avoid inconsistency between measures and goals.

At the same time, this study also reveals an important issue: when the government is trying to guide public opinion, the first to reply is often female users, and female users

could arrive 30 minutes to an hour earlier than male users. In the crisis management and communications of public opinion, the source of information that appears first for a similar group of people often has an important role in the communications. Especially during a major pandemic, there is a mixture of information and people's understanding of the information is ambiguous. The group of people who are the first to reply to government-posted tweets can often play an important guiding role. In addition, as the credibility of the government during a pandemic is already vulnerable, the users who first appear in the comments on a tweet on Weibo are no less important than the government that publishes the tweet. When this group is predominantly female, and since female users' expression is usually more emotional and more likely to influence public opinion, female users play a very important role in the process and can even play an auxiliary role in guiding public opinion. Therefore, for the guidance of public opinion under major public health incidents, the government can make good use of this characteristic, and take into account the changes in gender differences in different stages. The government should make use of the differences as much as possible to help achieve effective guidance of public opinion, fulfilling the goals with half the effort.

Finally, each local government needs to consider the characteristics of its own region when guiding public opinion. Under the basic principle of unified management of public opinion across the country, it is necessary to take into account the characteristics of each region as much as possible and take up measures such as conducting a secondary round of guidance, so as to achieve more effective control of public opinion.

This study explores the gender difference of public attitude to government guidance of major public health incidents. It laid a foundation for the future gender difference study in this era of growing gender differences. But it also has limitations. The NLP method could be updated to Bert. More gender differences reason could be focus. In this article, we didn't cover this. Future study can follow this direction and explore gender differences further. Future study can explore the effect of gender difference in major public health incident, and analysis of the government management and control methods for this problem. Future study can also focus on the characters of gender difference in major public health incident and mine the deeply reason of this difference.

References

[1]   W. T. Coombs, "Protecting Organization Reputations During a Crisis: The Development and Application of Situational Crisis Communication Theory," *Corporate Reputation Review,* vol. 10, no. 3, pp. 163–176, 2007.

[2]   D. Choudhury, Sharma, Logar, Eekhout, and Nielsen, "Gender and cross-cultural differences in social media disclosures of mental illness," in *proceedings of the Proceedings of the 2017 ACM conference on computer supported cooperative work and social computing*, 2017.

[3]   S. ELM, "Doing and undoing gender in a Swedish Internet community," 2007

[4]   X. Dong, "Self-representation of gender roles on Weibo and the dissemination offeminism," *Southeast Communication* vol. 4, no. 68-9, 2012.

[5]   K. Xue, L. Yu, and M. Yu, "Gender and generational differences in the use of political news in social media - An empirical analysis based on a survey of Chinese Internet users " *Shanghai Journalism Review,* no. 53-60, pp. 53-60, 2018.

[6]   J. Zhang, "Gender differences in social media-based political participation -- A study with the case of Facebook poll on "Brexit" " *China Economist,* pp. 192-194, 2017.

[7]   L. LI, Z. WANG, Q. ZHANG, and H. WEN, "Effect of anger, anxiety, and sadness on the propagation scale of social media posts after natural disasters," *Information Processing and Management,* vol. 57, 2020.

[8]   Q. Zong, Z. Huang, and S. Hongzhou, "A study of social media users' rumor-making and rumor-reporting behavior from the gender perspective " *Journal of Modern Information,* vol. 37, no. 7, 2017.

[9]   KLEMAN, "Journaling for the world to see: A proposed model of self-disclosure intimacy in blogs;," presented at the proceedings of the annual meeting of the National Communication Association, Chicago, IL, F, 2007.

[10]   Y. Zhang, Y. Dang, and H. Chen, "Research note: Examining gender emotional differences in Web forum communication," *Decision Support Systems,* vol. 55, pp. 851-860, 2013.

[11]   Z. Ye, N. H. Hashim, F. Baghirov, and J. Murphy, "Gender differences in instagram hashtag use," *Journal of Hospitality Marketing & Management,* 2017.

[12]   M. Zhang, " The gender divide in Internet use and public access to political information " *Southeast Communication,* vol. 9, 2010

[13]   X. Liu, M. Sun, and J. Li, "Research on gender differences in online health communities," *International Journal of Medical Informatics,* vol. 111, pp. 172-181, 2018.

[14]   X. Lin, K. A. Lachlan, and P. R. Spence, "Exploring extreme events on social media: A comparison of user reposting/retweeting behaviors on Twitter and Weibo," *Computers in Human Behavior,* vol. 65, pp. 576-581, 12// 2016, doi: http://dx.doi.org/10.1016/j.chb.2016.04.032.

[15]   T. Mikolov, I. Sutskever, K. Chen, G. S. Corrado, and J. Dean, "Distributed representations of words and phrases and their compositionality," in *Advances in neural information processing systems*, 2013, pp. 3111-3119.

[16]   T. Mikolov, K. Chen, G. Corrado, and J. Dean, "Efficient estimation of word representations in vector space," *arXiv preprint arXiv:1301.3781,* 2013.

[17]   X. Chen, T. Chang, and H. Wang, "Spatial and temporal analysis on public opinion evolution of epidemic situation about novel coronavirus pneumonia based on micro-blog data.," *Journal of Sichuan University(Natural Science Edition),* vol. 57, 2, 2020.

[18]   P. Rosenbaum and R. D., "The central role of the propensity score in observational studies for causal effects. ," *Biometrika,* vol. 70, no. 1, pp. 41–55, 1983. .

[19]   S. Becker and A. Ichino, "Estimation of average treatment effects based on propensity scores," *The Stata Journal,* vol. 2, no. 4, pp. 358–377, 2002.

[20]   Y. Lian, Z. Su, and Y. Gu, "Evaluating the Effects of Equity Incentives Using PSM: Evidence from China," *Front. Bus. Res. ,* vol. 5, no. 2 pp. 266–290, 2011.

[21]   J. Lin, S. Lin, and J. Guo, "The double-edged sword effect of social media overload on users' willingness to discontinue use," *Chinese Journal of Management,* vol. 16, no. 4, pp. 587-594, 2019.

Technological Innovation and Enterprise Capacity Utilization

Xiaoxin YANG[1]
School of Economics, Shanghai University, Shanghai, China

Abstract. China has now entered a stage of high-quality development. Realizing the transformation and upgrading of the manufacturing industry in the new stage is conducive to promoting China's high-quality development process. However, the current problem of insufficient capacity utilization in the manufacturing industry will affect its transformation and upgrading. From the perspective of micro-enterprises based on the data of 1,628 A-share listed companies in China's manufacturing industry, this paper uses a random panel Tobit model to study the impact of technological innovation on enterprise capacity utilization. The research results show that technological innovation promotes the optimization and upgrading of enterprise products, improves the production efficiency of enterprises, and effectively promotes the improvement of enterprise capacity utilization.

Keywords. Technological innovation, capacity utilization

1. Introduction

China's economy has now entered a stage of high-quality development from high-speed development, and building a modernized economic system is the main goal at present. Under the new development pattern, the transformation and upgrading of the manufacturing industry, which is the foundation of the country, is an important link in the construction of a modern economic system. However, problems such as profit loss and rigid industrial organization structure caused by insufficient utilization of manufacturing capacity will hinder its transformation and upgrading. To improve capacity utilization in the manufacturing industry, China has introduced several policies, including eliminating outdated capacity and promoting enterprise mergers and reorganizations. However, the introduction of policies fails to improve the manufacturing capacity utilization to a reasonable level. How to improve the manufacturing capacity utilization substantively has become a difficult problem at present. In fact, in the context of China's gradual reforms, the innovations carried out by micro-subjects and the industrial structure upgrades that may result from them have a positive impact on capacity utilization. At the same time, China's "14th Five-Year Plan" pointed out that it is necessary to adhere to the core position of innovation in the overall situation of China's modernization drive, and to implement the innovation-driven development strategy. Based on the above background, an in-depth study of the relationship between technological innovation and capacity utilization is conducive to exploring ways to

---

[1] Corresponding Author, Xiaoxin Yang, School of Economics, Shanghai University, Shanghai, China; Email: Sarahssa@163.com

improve China's manufacturing capacity utilization and enriching the theory of innovation-driven development strategies.

Since China is still in the transition stage from a planned economy to a socialist market economy, Chinese academic circles generally seek ways to resolve the insufficient utilization rate of manufacturing capacity from external factors, such as the intervention of local governments in the investment and production of local enterprises [1], there are few researches on the innovation factors originating from the enterprise. In addition, the direction of the role of innovation remains controversial. Starting from the promotion of market demand, some scholars believe that innovation can effectively improve the capacity utilization rate of enterprises [2]. Other scholars, starting from the bias of technological progress, believe that some China's existing innovation behavior will reduce the capacity utilization rate [3]. To this end, based on the related research on capacity utilization, this paper deeply studies the relationship between technological innovation and capacity utilization, in order to make contributions to related fields.

2. Theoretical Analysis and Research Hypothesis

Technological innovation can be divided into product innovation and process innovation. Product innovation refers to the introduction of new products or services by enterprises in order to meet market demand, while process innovation refers to the development of new elements in the process of production or service operations to produce products or provide services [4]. On the one hand, the entry of new products or services into the market can easily lead to market instability, and the emergence of high-tech, high-value-added products can break the existing competition pattern [5]. Innovation promotes the optimization and upgrading of enterprise products and enhances product market recognition. Through the implementation of product innovation strategies, enterprises are conducive to expanding market demand, and the increase in market demand will significantly improve the capacity utilization rate of enterprises [6]. On the other hand, process innovation brings improvements in production methods and processes for enterprises, which greatly improves the production accuracy and production efficiency of enterprises. Increased precision means higher performance in production and fully guaranteed product quality. The improvement of production efficiency can reduce the loss of materials and the waste of resources such as manpower and equipment in the production process. Enterprises with high production efficiency and high precision can effectively use existing production equipment to meet external production needs without the need for large-scale expansion of production capacity. Based on the above discussion, this paper proposes the following research hypothesis H:

Hypothesis H: Technological innovation is positively correlated with enterprise capacity utilization, and innovation promotes enterprise capacity utilization.

3. Research Design and Model Construction

3.1 Sample selection and data sources

This paper selects Chinese manufacturing A-share listed companies as the research object, and the time span is from 2016 to 2020. In the process of sample selection, ST*, ST, SST company samples were eliminated; Eliminate the samples of companies with

missing financial data and abnormal indicators. After the above adjustment, the data of 1,628 listed companies were finally obtained, with a total sample amount of 8,140. In order to eliminate the influence of inflation factors, producer price index is used to adjust the main business income of listed companies, and GDP deflator is used to adjust other financial data, taking 2010 as the base year. The financial data of listed companies come from WIND database, and the PPI and GDP deflator come from China Statistical Yearbook.

3.2 Capacity utilization measurement

So far, the mainstream methods of capacity utilization measurement include peak method [7], function method [8-9], data envelope method [10-11], etc. The peak method is based on the peak output, but the peak output cannot confirm whether the production capacity is fully utilized. The function method needs to set specific function form, but the production behavior of Chinese enterprises is easily disturbed by external factors, so it is difficult to set the function. Compared with the above methods, the advantage of data envelope method (DEA) is that it does not need to set the production or cost functions of enterprises, and it does not need input-output prices and other difficult data to obtain, so it is more suitable for this study. Therefore, this paper chooses DEA to measure the capacity utilization rate.

It is assumed that input factors include fixed input F, variable input V and technology level $TECH$. Under the data envelement method (DEA) measurement method, the production capacity can be expressed as $Y(F)$, while the actual output is constrained by variable input and technology level and expressed as $Y(F,V,TECH)$. Since technical level $(TECH)$ is difficult to measure directly, technical efficiency $TE(0 \leq TE \leq 1)$ is used instead, and actual output is further expressed as $TE*Y(F,V)$. Technical efficiency can be interpreted as the output shortage caused by relatively backward technology in the production process. By comparing the actual output with the production capacity, the capacity utilization ratio (CU) can be obtained, and the formula is as follows:

$$CU = Y(F,V,TECH)/ Y(F) = TE*Y(F,V)/ Y(F) = TE*EU \qquad (1)$$

Where, $EU = Y(F,V)/ Y(F)$ is the utilization rate of equipment, reflecting the utilization efficiency of production equipment under variable input constraints. The effective output function $Y(F,V)$ and $Y(F)$ are calculated by DEA method. In the calculation process, fixed assets, labor input and raw materials are selected as input variables, and operating income as output variables. Net fixed assets at the end of the year, the annual average number of employees, the cash flow statement of "purchase of goods, the payment of services", main business income. The model is output oriented BBC model, and the calculation software is MAXDEA8.21.

3.3 Empirical test model design

In order to verify the hypothesis proposed above, this paper constructed the following model to test the impact of technological innovation on enterprise capacity utilization:

$$CU_{i,t} = \beta_0 + \beta_1 RD_{i,t} + \beta_2 Demand_{i,t} + \beta_3 Capital_{i,t} + \beta_4 Share_{i,t} + \beta_5 Turnover_{i,t} + \beta_6 Lev_{i,t} + \varepsilon_{i,t} \qquad (2)$$

$CU_{i,t}$ represents the capacity utilization rate of i company (enterprise) in t year; $RD_{i,t}$ represents the innovation level of the enterprise; $Demand_{i,t}$ represents the external market demand faced by the enterprise; $Capital_{i,t}$ represents the capital intensity of the

enterprise; $Share_{i,t}$ represents the ownership concentration of the enterprise; $Turnover_{i,t}$ represents the total asset turnover of the enterprise; $Lev_{i,t}$ represents the asset-liability ratio of the enterprise; ε_i is the error term. Variable definitions and measurement methods are shown in Table 1.

Table 1. Variable Definition and Measurement

Variable Attributes	Variable Code	Variable Meaning	Variable Measuring
Explained Variable	CU	Capacity Utilization	DEA
Explanatory Variable	RD	Technological Innovation	Expenditure of R&D activities, take logarithm
Control Variables	Demand	Market Demand	Growth rate of operating income
	Capital	Capital Concentration	Fixed Assets/Total Assets
	Share	Ownership Concentration	Shareholding ratio of the largest shareholder
	Turnover	Total Asset Turnover	Operating Income/Total Assets
	Lev	Debt Asset Ratio	Total Liabilities/Total Assets

(1) Explained variable. The explained variable is enterprise capacity utilization rate, which is calculated by data Envelopment Method (DEA).

(2) Core explanatory variable. The core explanatory variable is technological innovation level, which is measured logarithmically by the expenditure of R&D activities.

(3) Control variables. Market environment and other enterprise factors also affect enterprise capacity utilization, so some control variables need to be added to improve the explanatory degree of the empirical model. In this paper, market demand, capital intensity, equity concentration, total asset turnover and asset-liability ratio are selected as control variables, and the growth rate of operating income, proportion of fixed assets to total assets, proportion of the largest shareholder, ratio of operating income to total assets and proportion of total liabilities to total assets are respectively used to measure.

4. Empirical results and analysis

Considering that the value of capacity utilization rate is between 0 and 1, which has an obvious truncation property, this paper adopts the random effect panel Tobit model (column 1) to empirically test the relationship between technological innovation and capacity utilization rate. To ensure the robustness of the regression results, the results were compared using a random-effects model (column 2), a fixed-effects model (column 3), and a mixed-effects model (column 4). In Table 2, the regression results of models 1-4 all show that the regression coefficient of R&D investment on capacity utilization is significant at the 1% confidence level, indicating that enterprises increase R&D investment and promote innovation and development to promote capacity utilization. Hypothesis 1 is established. The reason is that, on the one hand, R&D innovation promotes the optimization and upgrading of enterprise products, effectively increasing the technical content, and added value of products. The company thus has the potential for market expansion. The increase in market demand means that companies can greatly digest production capacity, and the utilization rate of production capacity is thus improved. On the other hand, R&D and innovation activities are the fundamental source of improving the technological level of enterprises. R&D innovation brings

improvements in the production methods and processes of enterprises, which is conducive to improving the production efficiency of enterprises and promoting the utilization rate of enterprises' production capacity.

Table 2. Empirical Regression Results

	(1)	(2)	(3)	(4)
RD	0.025***	0.027***	0.037***	0.033***
	(14.01)	(15.60)	(28.05)	(25.53)
Demand	0.001***	0.002***	0.002***	0.002***
	(4.25)	(5.00)	(4.31)	(3.51)
Capital	-0.307***	-0.299***	-0.328***	-0.165***
	(-18.57)	(-18.69)	(-24.14)	(-12.79)
Share	0.011	0.025	0.030***	0.060***
	(0.60)	(1.42)	(2.59)	(4.89)
Turnover	0.313***	0.268***	0.219***	0.242***
	(50.18)	(48.54)	(48.01)	(54.21)
Lev	-0.014	-0.009	0.062***	0.043***
	(-1.22)	(-0.79)	(6.56)	(4.40)
_cons	0.127***	0.128***	0.055***	0.028**
	(7.40)	(7.76)	(4.74)	(2.48)
Year FE	NO	NO	YES	NO
Industry FE	NO	NO	YES	NO
R^2		0.3598	0.4668	0.3755
σ_u	0.136***			
	(51.63)			
σ_e	0.081***			
	(111.60)			
Wald	3655.93***	3531.26***		
N	8140	8140	8140	8140

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The following article is the same.

The regression results of the control variables are consistent with the actual social development. The regression coefficient of market demand (Demand) on enterprise capacity utilization rate is positive at the 1% confidence level in the four models, indicating that the increase in market demand is conducive to promoting the improvement of enterprise capacity utilization rate. In models 1-4, capital intensity (Capital) is negatively correlated with capacity utilization at the 1% confidence level. If the capital intensity of enterprises continues to be at a high level, it means that R&D innovation activities will face the dilemma of lack of scientific research funds, and the reduction of innovation activities is not conducive to improving enterprise performance. The ownership concentration (Share) is positively correlated with the capacity utilization rate in Model 3-4 at the 1% confidence level, indicating that increasing the ownership concentration promotes the improvement of the enterprise capacity utilization rate. The increase in equity concentration enables controlling shareholders to have higher control over strategic decision-making, which in turn can reduce the resistance to advancing R&D projects. The relationship between total asset turnover (Turnover) and capacity utilization is also relatively robust, and is positively correlated at the 1% confidence level in all four models. The total asset turnover ratio reflects the overall operating efficiency of the enterprise. High operating efficiency means that the enterprise has strong project planning and implementation capabilities, which can aid with R&D activities. In models 3-4, the regression coefficient of the asset-liability ratio (Lev) to capacity utilization is significantly positive at the 1% confidence level. R&D and innovation activities last for a long time. In the process of project operation, it is necessary to continuously provide

financial support and appropriately increase the asset-liability ratio to ensure the steady progress of R&D and innovation activities.

5.Conclusions

From the perspective of micro-enterprises, based on the data of 1,628 A-share listed companies in China's manufacturing industry, using the random panel Tobit model, this paper studies the impact of technological innovation on enterprise capacity utilization and the regulatory effect of the institutional environment. The main research conclusions of the article are: technological innovation activities promote the optimization and upgrading of enterprise products, improve the production efficiency of enterprises, and effectively promote the improvement of enterprise capacity utilization. Based on the research findings, the following policy recommendations are put forward:

First, to promote R&D and innovation of enterprises and improve the overall technical level of the manufacturing industry. The current structural overcapacity problem in China's manufacturing industry is mainly caused by insufficient R&D innovation and backward technological level. Government departments can stimulate the willingness of manufacturing enterprises to innovate by implementing industrial policies that are inclined to the manufacturing industry, such as relaxing the conditions for the identification of manufacturing enterprises as high-tech enterprises. Enterprises receive tax incentives for R&D and innovation, increase investment in R&D and innovation, and further drive the increase in capacity utilization.

Second, build a basic technology sharing platform and promote enterprise cooperation and exchanges. At present, China does not have a basic technology reserve and sharing platform in the strict sense. Government departments should undertake the research and development of basic technology and establish a reserve of basic technology for China. At the same time, the technology reserve should be shared with public enterprises, so that all kinds of innovation entities can benefit from it, and pave the way for various industries in the early stage of innovation and development. In addition, government departments should also promote the exchange, study and cooperation of R&D and innovation activities among enterprises, and conduct technical interaction with the industry as a unit. Backward enterprises learn from advanced enterprises, and enterprises at the same level cooperate to overcome technical difficulties.

References

[1] Feitao Jiang, Qiang Geng, Dada LU, Xiaoping Li. Regional competition, institutional distortion, and the formation mechanism of overcapacity. China Industrial Economics,2012(06):44-56.
[2] Liguo Wang, Yueqing Gao. Research on overcapacity based on the perspective of technological progress. Research of Financial and Economic Issues,2012(02):26-32.
[3] Zhenbing Yang. Research of quantitative and technical economics,2016,33(08):30-46.
[4] Kexin BI, Dehua Sun. An empirical study on the synergistic development of product innovation and process innovation in manufacturing enterprises based on composite System Coordination Degree Model. China Soft Science,2010(09):156-162+192.
[5] Ping Li, Zhou Deng, Yanfang Zhang. Global computing power Competition pattern and China's Countermeasures under the new scientific and technological revolution and industrial transformation. Economic Review,2021(04):33-42+2.

[6] Tsai K H, Hsieh M H, Hultink E J. External technology acquisition and product innovativeness: The moderating roles of R&D investment and configurational context. Journal of Engineering & Technology Management,2011, 28(3):184-200.

[7] Klein, L.R. Some Theoretical Issues in the Measurement of Capacity. Econometrica,1960,28,272-286

[8] Kim, H. Y. Economic capacity utilization and its determinants: theory and evidence. Review of Industrial Organization,1999, 15(4), 321-339.

[9] Berndt E R, Morrison C J. Capacity utilization measures: Underlying economic theory and an alternative approach. American *Economic* Review,1981,71(2): 48−52. 38.

[10] Fare, R, Grosskopf, et al. Measuring Plant Capacity, Utilization and Technical Change-A Nonparametric Approach. International Economic Review,1989,30:655-666.

[11] Minjie Dong, Yongmei Liang, Qizai Zhang. Chinese industrial capacity utilization: industry comparison, regional gap and influencing factors. Economic research journal, 2015,50(01):84-98.

Digital Information Mobility Schema: A Data-Flow Model Featuring Risk-Resilient Approach Towards Effective Construction Worksite Synergy Utilizing Fuzzy-Analytic Hierarchy Process

Dante L. SILVA[a], Bernard S. Villaverde[a], Vhea Anne M. AGAPITO[a], Patricia Marie V. LOO[a], and Neil Martin C. OLAIS[a]

[a] *School of Civil, Environmental, & Geological Engineering, Mapua University, Manila, Philippines*

Abstract. The increasingly effective managing of risks in construction projects requires the stakeholders to collaborate, resulting in the need to integrate the use of Building Information Modelling (BIM) to mitigate the risks in project collaboration. Our understanding of strategic planning of BIM adoption amidst a pandemic is still limited, and it is widely accepted that COVID-19 is a long-term pandemic that require a constant and innovative range of mitigation approaches to protect public health. The significant construction advances emphasize remote work and digital tools that assist in the project's on-time completion. A fully digitalized approach is necessary for service continuity and rapid processing, particularly during a pandemic. Therefore, this study develops an adaptive digital collaboration framework based on Cloud-Based BIM technology to reduce risks while increasing workplace productivity and mobility. It resulted in a new way of managing the project information, enhancing the design team collaboration, and transforming 2D plans into 3D models. It integrates information to take a building through a virtual construction process long before it is completed, and each team member has access to the most up-to-date and current project information.

Keywords. Data Flow Model, Risk-Resilient Approach, Fuzzy-Analytic Hierarchy Process

1. Introduction

This study investigates project collaboration and data migration issues in the construction industry. The pandemic has hampered contractors worldwide [1]. It affected operations, productivity, expenditures, and profit in the construction business. Several ideas and frameworks are no longer useful, practicable, or enticing due to the economy [2]. Countries globally enforced global limitations, causing project delays, delayed production and distribution, material shortages, and stay-at-home orders.

Construction is becoming less effective and efficient [3]. Limited collaboration on and off the site has been one of the industry's major issues because most construction projects rely on strong productivity to deliver on schedule, and this depends on how well stakeholders can work together and communicate [4]. Most of the construction sector

has focused on remote work and digital solutions to keep projects on time due to these problems [5]. Integrating a fully digitalized procedure is crucial for service continuity and quick processing. Some projects required remote design, pushing contractors to find new ways to be productive. Since then, engaging with essential partners has been more important than ever. The Architectural Engineering and Construction (AEC) sector uses BIM more (Building Information Modeling). Leading engineers and contractors use 4D and 5D simulation to re-plan and optimize projects. They can also use the internet to track staff well-being, buy building supplies, and manage scarce resources more accurately [6].

As we accept this generation of modern technologies and advances, the construction sector continues to mature. These modifications pave the path for longer-lasting strategies and risk-resilient methods. Therefore, this study proposes and develops the digital collaboration framework based on Cloud-Based BIM, which aims to mitigate the risks in project collaboration while increasing workplace productivity and mobility [7]. The project's scope, productivity, and ultimate cost can all be enhanced with a collaboration framework. It unearths fresh approaches to handle risks and issues in the building sector to improve project performance, focusing on the project's execution, dependability, and operations [8].

This study aims to create a collaborative working environment for the AEC sector by developing a framework model that could assist in resolving the collaboration risks in the existing construction industry. Since it is difficult to obtain corporate software, the scope of this research is limited to the current information supplied by the creators, previous research papers, and data mining. This study's findings could help building industry experts better comprehend the challenges of model cooperation and the easily available market solutions.

This study investigates the risks associated with project collaboration in the context of the current construction industry climate. In response, the purpose of this project is to create an adaptable digital collaboration framework utilizing Cloud-Based BIM Technology to reduce risks and improve workplace productivity and mobility. Several steps were undertaken to achieve the study's objectives, including the identification of collaboration-related risks and cloud-based BIM advantages, gathering of data, evaluation, and assessment, and framework development.

2. Related Studies

Multi-criteria decision analysis (MCDA) is a scientific process used by professionals to determine the best option, categorize alternatives, or rank alternatives. The MCDA approach was employed when decision-makers had to choose amongst many competing criteria. It includes arranging and solving choice issues using various criteria [9]. The MCDA methods were applied to various areas of civil engineering such as structural engineering [10], geotechnical engineering [11], water resources engineering [12], transportation engineering [13], environmental engineering [14], and construction engineering [15]. This study implemented the Fuzzy-AHP approach which is likewise implemented in different areas of construction engineering including cost overruns [16], supplier selection [17], construction and demolition waste management [18], project delivery method [19], and change order in construction [20]. The current study implemented the fuzzy-AHP approach in creating data-flow framework model featuring risk-resilient approach towards effective construction worksite synergy.

When the pairwise comparison matrix is highly consistent, the triangular Fuzzy AHP is more suited since it gives alternative criterion rankings for references to prevent the subjectivity of a small number of experts when their opinion on the criteria is highly consistent. The triangular fuzzy AHP is also relevant when a sufficient number of factors are of comparable relevance and the relative importance of various criteria is near to one another [21]. In addition, in fuzzy AHP, the experts develop pairwise comparisons for the criteria and alternatives based on each criterion, with the values of the integrated comparisons and the pairwise comparison values of the experts being converted into triangular fuzzy numbers. In addition, the best option was stated with regard to the combination of priority weights for criteria and alternatives [22]

3. Methodology

This section of the paper presents the breakdown of steps and processes substantial in accomplishing the study's significant objectives, which are as follows: (1) assess the present condition of the construction industry and identify the risks associated with project collaboration, (2) determine the technological capabilities of the Cloud-Based BIM, (3) develop the adaptive digital collaboration framework, (4) evaluate the adaptability, functionality, and reliability of the framework, and (5) formulate a conclusion and recommendations regarding the success of the study towards minimizing risks and improving workplace productivity. Specifically, this part presented an overview of the research design, setting, study respondents, data-gathering procedures, and instruments.

3.1. PHASE 1: Identification of Collaboration-Related Risks and Cloud-Based BIM Benefits

From the review, researchers identified all probable and underlying project risks. This technique proved the researchers' initial premise that a deteriorating construction industry creates project collaboration hazards. This step analyzed publications, journals, studies, forums, and statements from companies that have used Cloud-based BIM Technology to determine its features and capabilities. The researchers examined how Cloud-Based BIM Technology might lessen the RBS risks. This process helped produce framework factors and tactics. Researchers grouped hazards into subcategories and rate benefits by area of concern. This approach was used to arrange risks by concentration and characterize them by probability and project impact.

3.2. PHASE 2: Data Collection, Analysis, and Interpretation

After the initial phase, the survey questionnaire is constructed based on the early findings to perform a survey study. Researchers surveyed AEC workers in the Philippines to collect data. Instead, researchers set a deadline for survey responders. The survey was distributed via email, and other online platforms.   The test findings were interpreted descriptively. The statistical treatment created the weights of variables for the Fuzzy Analytical Hierarchy Process, which validated the efficacy of the Adaptive Digital Collaboration Framework in minimizing risks and boosting workplace productivity and

mobility. Researchers developed variable weights from past statistical tests. Fuzzy AHP output was used to finalize the study framework.

3.3. PHASE 3: Framework Development

To oversee the initial development of the Digital Collaboration Framework, the researchers aggregated all the consideration elements and tactics gleaned from the first phase procedures' output. A further evaluation of the risks and rewards was conducted to determine where mitigation measures should be placed and successfully construct the framework. This was the primary activity of the study; this is where the actual framework creation began. Before evaluating the initial structure of the Adaptive Digital Collaboration Framework, the researchers regularly examined the accumulated aspects and tactics to identify defects for revision and improve the framework's quality.

3.4. Statistical Treatment

The researcher's statistical treatment started from the first phase of the study during the correlation analysis of the present condition of the construction industry with the risks related to project collaboration. The researchers did the following statistical treatment once the researchers have collected all the data from the qualified respondents within the given timeline. To interpret and summarize the gathered data, the researchers initially performed descriptive statistical treatment such as mean, geometric mean, standard deviation, and test for skewness [23]. The researchers used these data interpretation methods to transform the factors assessed numerically. The researchers used a Fuzzy AHP to predict the framework's adaptability, reliability, and functionality success [24]. In performing the Fuzzy AHP, the researchers derived the weights of each variable from the output of the previous statistical tests [25]. The output for the Fuzzy AHP was the basis of the finalization of the framework and study.

4. Result and Discussions

4.1. Risks in Project Collaboration

Since the researchers opted to utilize a Likert scale to get feedback from respondents, the most probable and possible interpretation of the results would be to get its weighted mean. However, before moving on to the Fuzzy AHP, the researchers divided the risks into clusters to mainly categorize them, which can significantly help build the framework and provide a better division of items for pairwise comparison matrices. The clustered items are presented in Figure 2.

Table 1 shows the derived intervals based on the weighted mean difference used by the researchers to get the triangular fuzzy number of each risk item. Each fuzzy number represents the level of priority of each risk [26].

Table 1. Triangular Fuzzy Numbers Based on Weighted Mean Difference

Weighted Mean Difference	Fuzzy Number	Triangular Fuzzy Scale	Inverse Value	Linguistic Term
0.00	1	(1, 1, 1)	(1, 1, 1)	Equal Priority
0.01 – 0.1088	2	(1, 2, 3)	(1/3, 1/2, 1)	Equal to Weak Priority
0.1089 – 0.2077	3	(2, 3, 4)	(1/4, 1/3, 1/2)	Weak Priority
0.2078 – 0.3066	4	(3, 4, 5)	(1/5, 1/4, 1/3)	Weak to Strong Priority
0.3067 – 0.4055	5	(4, 5, 6)	(1/6, 1/5, 1/4)	Strong Priority
0.4056 – 0.5044	6	(5, 6, 7)	(1/7, 1/6, 1/5)	Strong to Very Strong Priority
0.5045 – 0.6033	7	(6, 7, 8)	(1/8, 1/7, 1/6)	Very Strong Priority
0.6034 – 0.7022	8	(7, 8, 9)	(1/9, 1/8, 1/7)	Very Strong to Extreme Priority
0.7023 – 0.80	9	(9, 9, 9)	(1/9, 1/9, 1/9)	Extreme Priority

The BIM benefits includes BIM allows multi-disciplinary information integration to produce more informed and effective design and construction risk reduction solutions (B1), Reduces risks associated with inefficient stakeholder communication during project management (B2), Inter-stakeholder collaboration may decrease design risk throughout the decision-making process (B3), Reduced risks during construction and implementation due to BIM's collision detection algorithm (B4), Allows risk mitigation to be handled more quickly by keeping track of the project and reducing project uncertainty (B5), Assists with risk assessment and mitigation throughout the project life cycle (B6), It helps the project participants share risk information, helping to raise everyone's understanding of potential risks (B7), Enables change management via regular revision control on a shared platform (B8), Reduces construction risks by providing geographical data on potential risk occurrences (B9), Can reduce the design errors and reworks (B10), Enhances and improves the overall quality of the project design (B11), Can be of assistance in design cooperation and work-sharing (B12), Increases the project team's productivity (B13), Reduces the need for re-gathering and re-formatting of data (B14), Simplifies file management and access to drawings for faster evaluation (B15), An effective communication platform during the time of the pandemic (B16), A reliable basis for decision-making in the entire project life cycle (B17), Facilitates collaboration through high-frequency data management for all the disciplines involved in the project (B18), Allows the project stakeholders to achieve a joint objective of the project (B19), Provides construction stakeholders more excellent visualization of project information (B20), Can capture and maintain the essential knowledge among relevant stakeholders, enabling them to examine the feasibility of reusing building components for projects (B21), Provides access to the most up-to-date project documents to all disciplines (B22), Aid in developing more sustainable infrastructure that meets the needs of its owners and occupants by assisting in the provision of necessary value judgments (B23), An aid to overcome challenges such as information loss, ownership, and legal disputes (B24), and Enhances cooperation between project team members (B25). The stacked bar chart representation of the benefits of using BIM is shown in Figure 3.
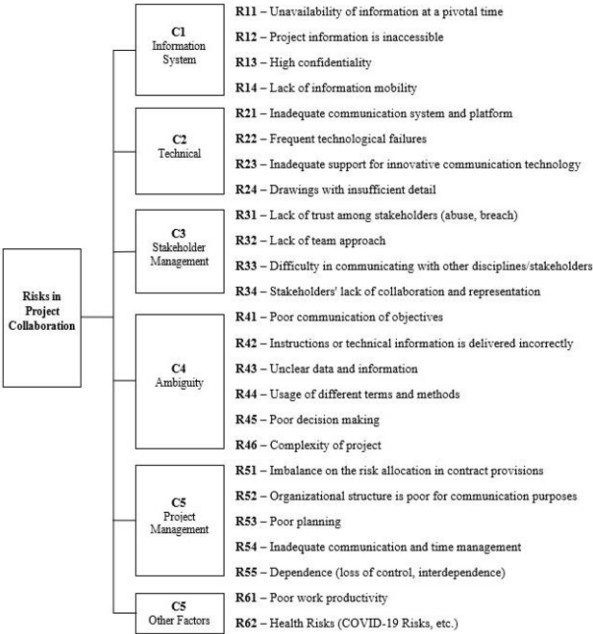
Figure 1. Clustered Risk Items
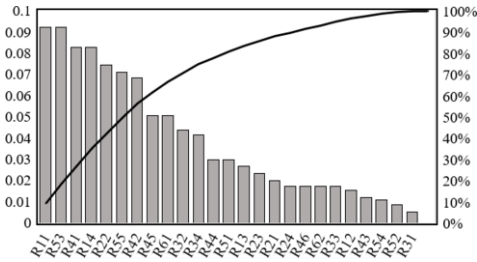
Figure 2. Clustered Risk Items
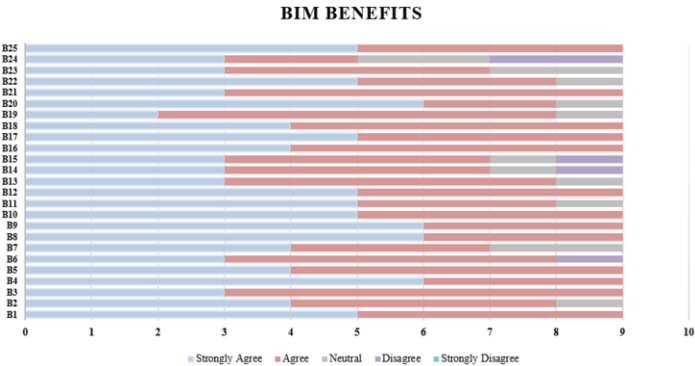
Figure 3. Stacked Bar Chart representation of the benefits of using BIM

BIM benefits have been quantified extensively (BIM). Despite widespread use, relationships between project risks and BIM advantages were studied. BIM provides multi-disciplinary information integration to produce better informed and effective design and construction risk reduction solutions, as indicated in the first category of project collaboration hazards [27]. Sharing risk information helps project participants identify potential risks. BIM-experienced respondents validated this notion. BIM is said to lessen risks during construction and implementation due to its collision detection algorithm [28].

All partners in a joint effort must be committed. Each stakeholder should know their role in the team and have clear responsibilities. Flexible organizations can benefit from the pooled connectivity and project effectiveness. Maintaining clear communication lines is a risk in project collaboration. These risks can be minimized with BIM because it: (I) provides construction stakeholders with better visualization of project information; (II) improves cooperation between project team members; (III) captures and maintains essential knowledge among relevant stakeholders, allowing them to examine the feasibility of reusing building components for projects. Ambiguities in construction projects typically result from the project's complexity, inaccurate instructions or technical information, imprecise data and information, and bad decision making. BIM is a design program whose documentation flows from planning to implementation. It helps overcome information loss, ownership, and legal conflicts, minimizes the need to re-gather and re-format data, and aids design cooperation and work sharing. BIM may mitigate project management risks including imbalanced risk distribution in contract conditions by providing up-to-date project documents to all disciplines [29]. Poor planning, communication, time management, and interdependence can be reduced by sharing risk information among project participants. High-frequency data management helps all project disciplines collaborate.

Furthermore, it allows risk mitigation to be handled more quickly by keeping track of the project and reducing project uncertainty. Lastly, it simplifies file management and access to drawings for faster evaluation. Other factors for the risks in construction include poor work productivity and health risks such as COVID-19. Since we are in a pandemic, BIM offers an effective communication platform during the pandemic, enhancing and improving the overall quality of the project design. This provides a secure collaboration environment where the design team, construction team, and client can access, view, and share building design modeling and document development.

4.2. Framework Development

The formulated framework is a systematized strategy that aims to achieve effective collaboration and information mobility in all aspects of the project and mitigate the significant risks related to project collaboration. The framework strives to make the collaboration between stakeholders simpler and faster, thus resulting in orderly workplace productivity.

The framework consists of four (4) main phases, including project planning, design and collaboration, construction, and operation to achieve seamless workplace collaboration and mobility. This framework could help the construction industry enter a new era where they could have the confidence to do every job coordinately and coherently despite the given situation (pandemic era). Three of the framework's phases were retrieved from the manual work or traditional construction methodology. At the

same time, there is an additional step based on the BIM process associated with cloud technology.
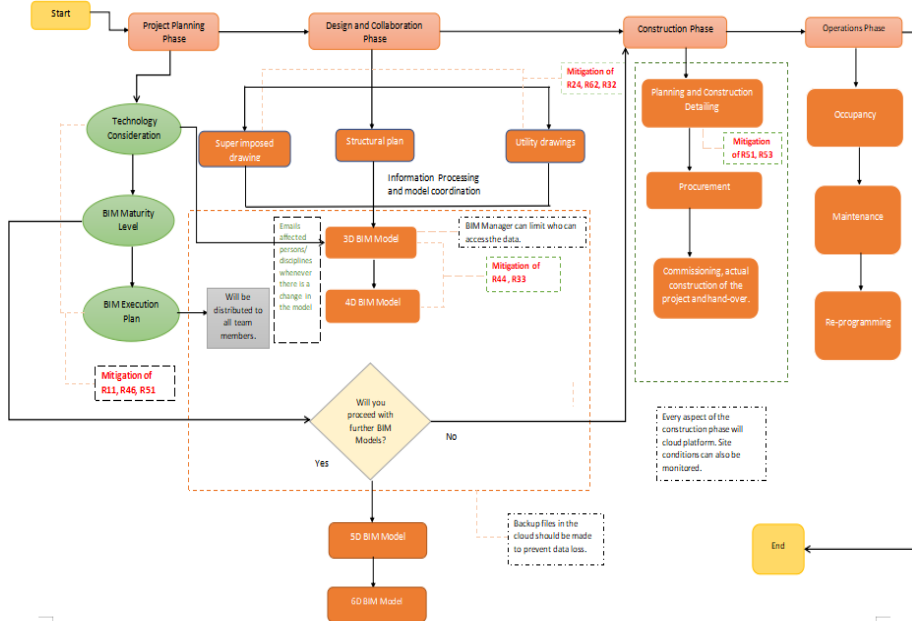
Figure 4. Developed Cloud-Based BIM Framework

5. Conclusion

The scarcity of collaboration and trust in the present-time construction industry caused friction and disagreements, affecting the project's design, quality, and output, compelling the industry to embrace more advanced technologies and enhance remote work activities to counter this situation.

This study discussed how the digital collaboration framework is significant to the construction industry by unveiling the common risks that the industry is facing in its present condition, as well as implementing enabling factors and proposing risk mitigation techniques that might help enhance workplace productivity, efficiency, and collaboration between project participants and improve project outcomes. This study also emphasized that collaboration challenges and obstacles brought by the pandemic, such as unprecedented delays, interruptions, and unpredictability in construction projects, can be overcome through digital solutions by enhancing integration, partnering, and contractual governance. Aside from risks, the study also validated the benefits of Cloud-Based BIM in the construction industry. The validation results have helped assess the framework's capability and effectiveness in mitigating the risks.

Different degrees of data security and network speeds risk data loss across organizations. Difficulties may occur in management due to variances in Cloud-Based BIM knowledge among the AEC sector that utilize various professional models. In addition, different BIM standards and specifications could result in the loss of information and hinder collaboration. These issues should be addressed immediately to

prevent future disputes. Only the function of BIMs in minimizing risks in project cooperation was studied and interpreted. Future study is required to merge managerial and technical components, requiring relevant BIM software. Lastly, the integrated management of the ultimate risk reduction approach must be validated in a real-world project.

References

[1] Oladimeji O. Influence of COVID-19 pandemic on local construction firms' viability. J. Eng. Des. Technol. 2022;20(1): 201-221.

[2] Silva D, de Jesus KL, Villaverde B, Torre RGD, Espero N, Fermin KJ, Ramirez RR. Post-pandemic Project Change Management Model: An Adaptable Framework Utilizing Levenberg–Marquardt Algorithm and Dynamic Causal Loop Diagram for Construction Innovation. In Proc. 2021 4th Int. Conf. Civ. Eng. Archit. 2022; 587-600.

[3] Silva D, Villaverde B, De Jesus KL, Marcial Jr ER, Villa-Real CV, Zarrage JM. Design initiative implementation framework: A model integrating kolmogorov-smirnov in sustainable practices for triple-bottom-line principles in construction industry. Civ. Eng. Archit., 2020;8(4): 599-617.

[4] Macariola RN, Silva DL. Coping with the information age: development of A data flow diagram-based knowledge management system for mitigating delays for construction. In IOP Conf. Ser.: Mater. Sci. Eng. 2019 Oct; 652(1): 012070.

[5] Newman C, Edwards D, Martek I, Lai J, Thwala WD, Rillie I. Industry 4.0 deployment in the construction industry: a bibliometric literature review and UK-based case study. Smart Sustain. Built Environ. 2020;10(4): 557-580.

[6] Vilutiene T, Kalibatiene D, Hosseini, MR, Pellicer E, Zavadskas EK. Building information modeling (BIM) for structural engineering: A bibliometric analysis of the literature. Adv. Civ. Eng. 2019: 2019.

[7] Alreshidi E, Mourshed M, Rezgui Y. Requirements for cloud-based BIM governance solutions to facilitate team collaboration in construction projects. Requir. Eng. 2018;23(1): 1-31.

[8] Silva D, De Jesus KL, Villaverde B, Enciso AI, Mecija AN, Mendoza JO. Interdisciplinary Framework: A Building Information Modeling Using Structural Equation Analysis in Lean Construction Project Management. Mod. Manag. Based Big Data II Mach. Learn. Intell. Syst. III: Proc. MMBD 2021 MLIS 2021 2021; 341: 234.

[9] Nadkarni RR, Puthuvayi B. A comprehensive literature review of Multi-Criteria Decision Making methods in heritage buildings. J. Build. Eng. 2020;32: 101814.

[10] Harirchian E, Jadhav K, Mohammad K, Aghakouchaki Hosseini SE, Lahmer T. A comparative study of MCDM methods integrated with rapid visual seismic vulnerability assessment of existing RC structures. Appl. Sci. 2020;10(18): 6411.

[11] Heidarie Golafzani S, Eslami A, Jamshidi Chenari R, Hamed Saghaian M. Optimized selection of axial pile bearing capacity predictive methods based on multi-criteria decision-making (MCDM) models and database approach. Soft Comput. 2022; 1-17.

[12] Akbari M, Meshram SG, Krishna RS, Pradhan B, Shadeed S, Khedher KM, Sepehri M, Ildoromi AR, Alimerzaei F, Darabi F. Identification of the groundwater potential recharge zones using MCDM models: Full consistency method (FUCOM), best worst method (BWM) and analytic hierarchy process (AHP). Water Resour. Manag. 2021; 35(14): 4727-4745.

[13] Mavi RK, Zarbakhshnia N, Khazraei A. Bus rapid transit (BRT): A simulation and multi criteria decision making (MCDM) approach. Transp. Policy 2018; 72: 187-197.

[14] Mahammad S, Islam A. Evaluating the groundwater quality of Damodar Fan Delta (India) using fuzzy-AHP MCDM technique. Appl. Water Sci. 2021; 11(7): 1-17.

[15] Chalekaee A, Turskis Z, Khanzadi M, Ghodrati Amiri G, Keršulienė V. A new hybrid MCDM model with grey numbers for the construction delay change response problem. Sustainability 2019; 11(3): 776.

[16] Afzal F, Yunfei S, Junaid D, Hanif MS. Cost-risk contingency framework for managing cost overrun in metropolitan projects: Using fuzzy-AHP and simulation. Int. J. Manag. Proj. Bus. 2020; 13(5): 1121-1139.

[17] Biruk S, Jaskowski P, Czarnigowska A. Fuzzy AHP for selecting suppliers of construction materials. In IOP Conference Series: Mater. Sci. Eng. 2019; 603(3): 032093.

[18] Khoshand A, Khanlari K, Abbasianjahromi H, Zoghi M. Construction and demolition waste management: Fuzzy Analytic Hierarchy Process approach. Waste Manag. Res. 2020; 38(7): 773-782.

[19] Comu S, Kural Z, Yucel B. Selecting the appropriate project delivery method for real estate projects using fuzzy AHP. J. Constr. Eng. 2020; 3(4): 249-263.

[20] Gunduz M, Mohammad KO. Assessment of change order impact factors on construction project performance using analytic hierarchy process (AHP). Technol. Econ. Dev. Econ. 2020; 26(1): 71-85.

[21] Chan HK, Sun X, Chung SH. When should fuzzy analytic hierarchy process be used instead of analytic hierarchy process?. Decis. Support Syst. 2019;125: 113114.

[22] Hanine M, Boutkhoum O, Tikniouine A, Agouti T. Comparison of fuzzy AHP and fuzzy TODIM methods for landfill location selection. SpringerPlus 2016;5(1): 1-30.

[23] Thekkuden DT, Mourad AHI. Investigation of feed-forward back propagation ANN using voltage signals for the early prediction of the welding defect. SN Appl. Sci. 2019;1(12): 1-17.

[24] Figueiredo K, Pierott R, Hammad AW, Haddad A. Sustainable material choice for construction projects: A Life Cycle Sustainability Assessment framework based on BIM and Fuzzy-AHP. Build. Environ. 2021;196: 107805.

[25] Liu Y, Eckert CM, Earl C. A review of fuzzy AHP methods for decision-making with subjective judgements. Expert Syst. Appl. 2020;161: 113738.

[26] Butdee S, Phuangsalee P. Uncertain risk assessment modelling for bus body manufacturing supply chain using AHP and fuzzy AHP. Procedia Manuf. 2019;30: 663-670.

[27] Shadram F, Mukkavaara J. An integrated BIM-based framework for the optimization of the trade-off between embodied and operational energy. Energy Build. 2018;158: 1189-1205.

[28] Zou Y, Kiviniemi A, Jones SW. A review of risk management through BIM and BIM-related technologies. Saf. Sci. 2017;97: 88-98.

[29] Sami Ur Rehman M, Thaheem MJ, Nasir AR, Khan KIA. Project schedule risk management through building information modelling. Int. J. Constr. Manag. 2022;22(8): 1489-1499.

Forecasting Construction Cost Using Artificial Neural Network for Road Projects in the Department of Public Works and Highways Region XI

Donna Ville GANTE [a,1], Dante L. SILVA [b], and Meriam P. LEOPOLDO [c]

[a] *School of Graduate Studies, Mapua University, Manila, Philippines*
[b] *School of Civil, Environmental, & Geological Engineering, Mapua University, Manila, Philippines*
[c] *College of Engineering and Architecture, Mapua Malayan Colleges Mindanao, Davao, Philippines*

Abstract. The development of roads has been one of the nation's most essential infrastructural initiatives. It is an essential mode of transportation that plays an important role in our everyday lives. Because of its importance, the government has allotted large budgets in making roads in different parts of the country. The quantity and complexity of road construction projects have substantially expanded in recent years. Numerous novel methods and technology have been developed to facilitate road construction budgeting, planning, and decision-making. Using Artificial Neural Network (ANN), this study constructed a forecasting model to accurately anticipate the future costs of road improvements. Between 2017 and 2020, fifty (50) completed road projects from the Department of Public Works and Highways (DPWH) Regional Office XI were utilized by the researcher. The DPWH RO XI is one of the country's largest implementing offices for constructing public roads catering the entire Davao Region. This research used the project cost as the dependent variable while the independent variables are the construction activities' revised duration and variation order in running the model. Multiple linear regression model performance was compared to the performance of the neural network prediction model. The data included the major construction activities for road projects with its corresponding revised duration, actual and planned cost, and the reason for variation order. It demonstrates that the neural network models outperform to the multiple linear regression (MLR) model in terms of prediction accuracy. This research offers a model to the government agencies and contractors implementing road construction in predicting road construction costs more accurately.

Keywords. Construction Project Management, Project Cost, Construction Schedule, Artificial Neural Network

1. Introduction

A solid construction plan serves as the basis for developing a budget and timetable [1]. From a competitor's standpoint, estimate is a crucial step in the construction process. In

---

[1] Corresponding Author: Donna Ville L. Gante, School of Graduate Studies, Mapua University, Manila, Philippines, E-mail: dvlgante@mymail.mapua.edu.ph

fact, the true cost of the project was only be known once it has been completed, and the contractor could only make the projected profit if the estimated cost is less than or equal to the project's actual cost [2]. Project cost estimating faces several challenges throughout the process. Cost overruns, schedule delays, scope revisions, contingencies and inflation are all common obstacles [3]. In the road construction sector cost forecasting is one of the most important aspects of planning, budgeting, and decision-making. The greater the project's scope is understood, the more precise estimates may be provided, as more project needs are specified [4]. Prior knowledge of these expenditures is crucial for both the contractor and the owner. Using previous data to forecast future results, trend analysis was implemented which is a statistical technique and was achieved through monitoring cost and schedule variations [5].

Firms creating cost plans can utilize a list of standard elements from a published industry guide or create their own from a library of group and sub-elements. The goal of standardizing data is to guarantee that all functional components are identified. After determining the element descriptions, it is time to assign a target price to each, and one way to do so is to look for any data used to generate the budget as this would have already established a benchmark [6].

Cost and schedule discrepancies might create undesired consequences that would lead to low customer satisfaction. Creating new techniques and adopting innovations are essential to resolve some of the most frequently encountered problems in the construction industry [7]. Artificial Neural Networks are designed to train the input and output of data, they have the potential in showing updated results using the new training examples [8]. It was shown that positive applications of Artificial Neural Networks in terms of cost prediction, scheduling, risk assessment, claims and disputes, resolve outcomes and decision making [9].

This study attempts to estimate the future total cost of road construction projects by employing an artificial neural network and comparing it to a multiple linear regression model that can predict future costs. This research used the completed road projects under the DPWH Regional Office XI in forecasting the road project's actual-to-planned cost. The DPWH Region XI is one of the country's largest implementing offices for constructing public roads catering to the entire region XI.

2. Related Studies

All construction projects have costs and knowing those costs ahead of time is critical for both contractor and the owner. Trend analysis is a mathematical technique for predicting future outcomes based on historical data. This is accomplished by keeping track of cost and schedule variations. The ability to estimate future performance is one of the tangible benefits of comprehensive data collection and analysis [10]. The skeleton framework of a specified budget is constructed by dividing the cost limit into proportional sections or components of a project's scope of work. The need of including all parts must be highlighted, as eliminating one will only reveal the problem during the design process which is undesirable [11]. In the Philippines, the DPWH adopted the Standard Specifications for Highways, Bridges, and Airports where the major work activities are the facilities for engineers, other general requirements, subbase and base courses, surface courses, bridge construction, drainage, and slope protection structures, miscellaneous structures, and material details [12]. In an extensive review of previous research, an up-

to-date application of Artificial Neural Network were found in the context of cost, duration, risk analysis, productivity, safety, dispute, unit rate, and hybrid models. It authorizes the significance of ANNs in implementing a variation of forecast, sorting, enhancement, and creating framework of connected tasks in construction management [13]. ANN have better pattern recognition and learning abilities to get a reliable result [14].

3. Methodology

3.1. Data Collection, Analysis, and Interpretation

This phase involves the collection, organization, and analysis of data pertaining to construction scheduling to meet the study's primary purpose. The method of the data collection in this phase was through the collection of historical data from the DWPH Regional Office XI in Davao City specifically, road projects. After gathering the data that was discussed in the former process, identifying, and classifying each factor in a structured and detailed way.

3.2. Development of an ANN Model

Using the ANN model, the researcher conducted an effective assessment instrument of the established factors from the assessed and evaluated data obtained in the former process.

An ANN model for predicting the actual to planned cost ratio was developed using the following core features of the model: (a) Levenberg-Marquardt as the training algorithm (TA) [15], (b) hyperbolic tangent sigmoid as the activation function (AF) [16], and (c) "n" number of hidden neurons (HN), where "n" is the governing value. In identifying the final prediction model, the Pearson's correlation coefficient (R), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) was used as the performance markers of the final model [17].

3.3. Relative importance (RI) using Garson's Algorithm (GA)

The researcher determined the significance of input parameters to the output using GA. From the output from the previous phase, the researcher analyzed the regression plots of the ANN Model in determining the RI of each factor [18]. This showed which is the most significant factor and least significant factor to the actual-to-planned cost ratio.

4. Result and Discussions

4.1. Collection and Organization of Factors

The identification of the factor of road construction actual and planned cost came from the inferences of numerous literature reviews historical data. The researcher gathered historical data of the fifty (50) completed projects of DPWH Regional Office XI from 2017 to 2020. The data included the major construction activities for road projects with its corresponding revised duration, actual and planned cost, and the reason for variation

order. The major construction of activities on road construction based on the DPWH technical specifications are the facilities for the engineers (Factor 1), other general requirement (Factor 2), earthwork (Factor 3), sub-base and base course (Factor 4), surface courses (Factor 5), drainage (Factor 6), and slope protection (Factor 7).

4.2. Descriptive Statistics of the Dataset

The descriptive statistics of the dataset used in this study are presented in Table 1. It was shown that the highest mean was observed in Factor 2 (other general equipment), while the least was observed in Factor 3 (earthworks). The skewness of the data for all factors was observed to be greater than 1, which suggests that the dataset is highly skewed [19]. Moreover, the kurtosis values observed for all datasets were all greater than 1, which implies that the data distribution is too peaked [20].

Table 1. Artificial Neural Network Model simulations

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
N	50	50	50	50	50	50	50
Mean	148.96	156.70	105.80	106.58	122.50	125.00	146.70
Std. Dev.	179.25	182.22	178.32	162.06	165.70	166.41	179.20
Skewness	1.503	1.398	2.351	1.669	1.590	1.729	1.528
Kurtosis	1.998	1.707	6.387	2.514	2.453	3.445	2.353
Range	720.00	720.00	821.00	660.00	660.00	702.00	765.00

4.3. Development of an Artificial Neural Network Model

Using the core features of the model described in Section 2.2 including the TA, AF, and HN as well as the performance criteria such as R, MSE, and MAPE, the results of the model development for each of the hidden neurons simulated in this study was obtained and was shown Table 2 and Figure 1.

Table 2. Artificial Neural Network Model simulations

HN	R (Training)	R Validation	R (Testing)	R (All)	MSE	MAPE
1	0.89429	0.95602	0.99337	0.89651	5.412e-05	1.143%
2	0.91425	0.97218	0.95265	0.90717	4.7813e-05	1.030%
3	0.90760	0.97879	0.98647	0.90823	4.227e-05	0.996%
4	0.90899	0.95471	0.95201	0.91031	4.046e-05	0.995%
5	0.91224	0.95754	0.91906	0.91196	3.740e-05	0.978%
6	0.91447	0.90985	0.93166	0.91373	3.634e-05	0.897%
7	0.91684	0.93372	0.96832	0.91462	3.5209e-05	0.867%
8	0.92529	0.96259	0.96180	0.92533	3.0649e-05	0.863%
9	0.93314	0.97943	0.98641	0.93435	2.168e-05	0.834%
10	0.93385	0.98443	0.99095	0.93447	1.5642e-05	0.826%
11	0.93790	0.95139	0.99047	0.94782	1.5126e-05	0.677%
12	0.94469	0.98199	0.98765	0.95710	1.4495e-05	0.667%
13	0.95086	0.99909	0.98153	0.96215	1.4351e-05	0.624%
14	0.95826	0.98475	0.99897	0.98158	1.4003e-05	0.607%
15	0.96931	0.99936	0.99943	0.99216	8.4078e-06	0.541%
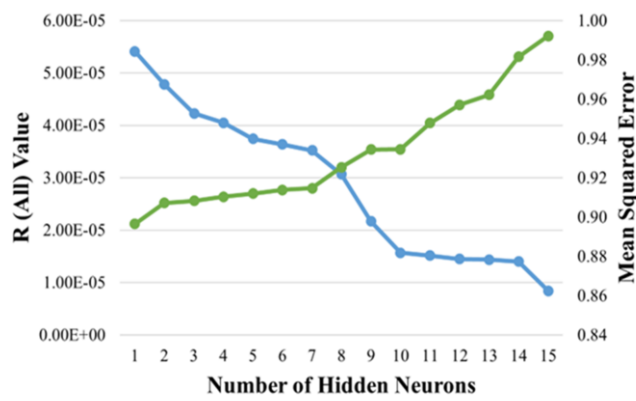
Figure 1. Impact of the Hidden Neurons on the R Value and MSE

Based on the simulations for the final prediction model, it was observed that the best model was seen in the results of the simulation of 15 hidden neurons, giving the largest R value and the least MSE and MAPE. This is similar to the suggestion made in the study of Gunduz and Sahin, wherein the number of HN is recommended to be 2m+1 [21]. The final model structure is 7-15-1 (input-hidden-output). The regression plots of the ANN model development phases are exhibited in Figure 2. The results show a very high R value almost equal to 1 [22].
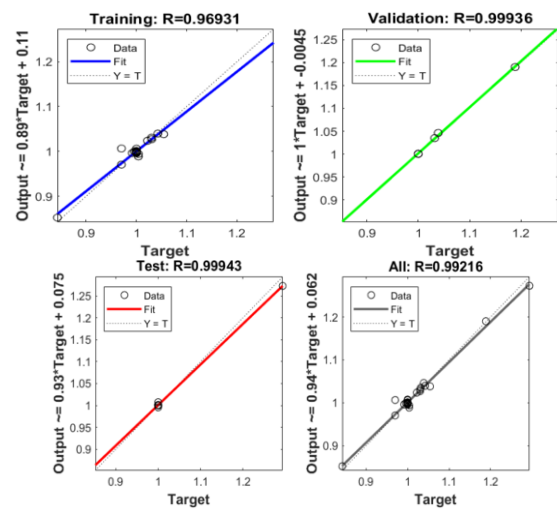
Figure 2. Regression Plots of Neural Network Model Development Phases

4.4. RI using GA

The RI of the input parameters was analyzed through their connection weights using GA. The calculation shows that the most significant parameter to the Actual to Planned Cost Ratio is Factor 4 (Sub-base and Base Course), while the least important factor is Factor 1 (Facilities for the Engineer). The relative importance of each factor is shown in Figure 3.
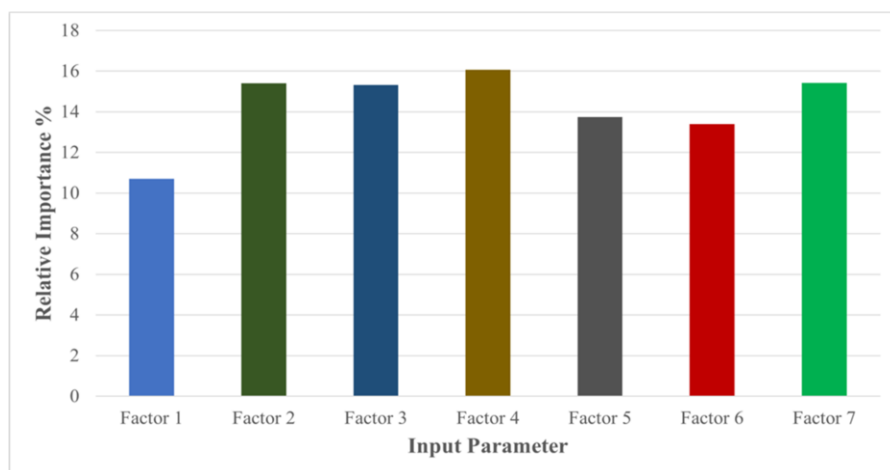
Figure 3. Regression Plots of Neural Network Model Development Phases

4.5. ANN and MLR Model Comparison

The performance of the created neural network prediction model was contrasted to the performance of a MLR model. It demonstrates that the neural network model is greater in terms of prediction accuracy as compared to that of the MLR model. The MAPE for the final neural network model is 0.541% while that of the multiple linear regression model is 2.480%. Figure 4 shows the prediction performance of the final neural network model and the multiple linear regression model [23].
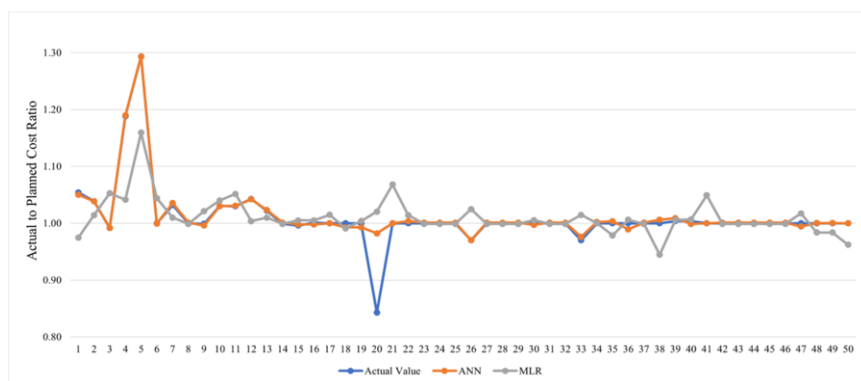
Figure 4. Regression Plots of Neural Network Model Development Phases

5. Conclusion

The purpose of this study is to develop an accurate predictive model for estimating future road project costs based on the project cost and the cost-influencing elements. According to the literature review and from previous research, prediction of construction costs is inaccurate for practical application due to various unanticipated and disruptive

phenomena. However, if properly developed they can attain a degree of precision that is advantageous to a variety of applications. Therefore, this research presents a more accurate tool in predicting actual-to-planned cost ratio for road projects. This research provided a mathematical tool in actual-to-planned cost ratio for government agencies and contractors in their preparation for future road projects.

This research has gone through an array of processes to achieve the results of the study. First, the study was able to identify the factors needed through the fifty (50) completed road projects from the DPWH regional office XI. The extracted data indicates that road projects followed the same construction activities, but had various project durations and reasons for variances, which influenced the variance between the projected and actual project costs. Based on the extracted data, the researcher used the Revised Duration and Reasons for Variation Order for each construction activity as factors in applying artificial neural network. This led the researcher to be able to make a record of descriptive statistics of the dataset. It follows that the factors in predicting actual-to-planned cost ratio are statistically significant in predicting actual-to-plan cost ratio. The extracted factors were used in creating the ANN model. After completing the ANN model, the RI of the factor was analyzed using GA. It was then found that the most significant factor to actual-to-planned cost ratio was the sub-base and base course, and the least important factor was the facilities for the engineer.

Lastly, the ANN model was compared to Multiple Linear Regression to test its accuracy in terms of predicting actual-to-plan cost. It showed that the ANN model is superior in terms of predication accuracy with a MAPE of 0.541%. This research concluded that the out of the fifty (50) completed projects of DPWH and seven (7) construction activities, the artificial neural network model can predict its actual-planned-cost ratio with high accuracy.

The researcher only used existing data and not assumptions in formulating the model. The existence of these data is of utmost importance to the development of this model. The study concentrated solely on local data from the DPWH Regional Office XI. Future research studies could opt to use more road projects as samples to improve accuracy and reduce inaccuracies. In addition, to increase the accuracy of the model, a future researcher could use more cost-influencing parameters when estimating the future cost of road improvements. The more detailed a prediction model is, the more it is advantageous to a variety of applications.

References

[1]   Wahab, A., & Wang, J. (2021). Factors-driven comparison between BIM-based and traditional 2D quantity takeoff in construction cost estimation. Engineering, Construction and Architectural Management.
[2]   Kumar, L., Jindal, A., & Velaga, N. R. (2018). Financial risk assessment and modelling of PPP based Indian highway infrastructure projects. Transport Policy, 62, 2-11.
[3]   Johnson, R. M., & Babu, R. I. I. (2020). Time and cost overruns in the UAE construction industry: a critical analysis. International Journal of Construction Management, 20(5), 402-411.
[4]   Tayefeh Hashemi, S., Ebadati, O. M., & Kaur, H. (2020). Cost estimation and prediction in construction projects: a systematic review on machine learning techniques. SN Applied Sciences, 2(10), 1-27.
[5]   Debnath, K. B., & Mourshed, M. (2018). Forecasting methods in energy planning models. Renewable and Sustainable Energy Reviews, 88, 297-325.
[6]   Lu, C., Liu, J., Liu, Y., & Liu, Y. (2019). Intelligent construction technology of railway engineering in China. Frontiers of Engineering Management, 6(4), 503-516.

[7]   Cabuñas, J. T., & Silva, D. L. (2019). Exploratory Factor-Item Analytic Approach for Construction Project Cost Overrun using Oblique Promax Rotation for Predictors Determination. International Journal of Innovative Technology and Exploring Engineering, 8(6s3), 47-54.

[8]   Manahan Malasan, C., S. Villaverde, B., L. Silva, D., & M. de Jesus, K. L. (2021, December). Artificial Neural Network with Sensitivity Analysis: Predicting the Flexural Strength of Concrete Pavement using Locally Sourced Dilapidated Concrete as Partial Replacement. In 2021 5th International Conference on Computer Science and Artificial Intelligence (pp. 408-414).

[9]   Waziri, B. S., Bala, K., & Bustani, S. A. (2017). Artificial neural networks in construction engineering and management. International Journal of Architecture, Engineering and Construction, 6(1), 50-60.

[10] Jardine, A. K., Lin, D., & Banjevic, D. (2006). A review on machinery diagnostics and prognostics implementing condition-based maintenance. Mechanical systems and signal processing, 20(7), 1483-1510.

[11] Towey, D. (2013). Cost management of construction projects. John Wiley & Sons.

[12] Standard Specifications for Highways, Bridges, and Airports (Vol. 2). (2012). DPWH.

[13] Kulkarni, P., Londhe, S., & Deo, M. (2017). Artificial neural networks for construction management: a review. Journal of Soft Computing in Civil Engineering, 1(2), 70-88.

[14] Alaloul, W. S., Liew, M. S., Wan Zawawi, N. A., Mohammed, B. S., & Adamu, M. (2018). An Artificial neural networks (ANN) model for evaluating construction project performance based on coordination factors. Cogent Engineering, 5(1), 1507657.

[15] LAROZA SILVA, D. A. N. T. E., & MARCELO DE JESUS, K. L. (2020, August). Backpropagation neural network with feature sensitivity analysis: pothole prediction model for flexible pavements using traffic and climate associated factors. In 2020 the 3rd international conference on computing and big data (pp. 60-67).

[16] Monjardin, C. E. F., de Jesus, K. L. M., Claro, K. S. E., Paz, D. A. M., & Aguilar, K. L. (2020, December). Projection of water demand and sensitivity analysis of predictors affecting household usage in urban areas using artificial neural network. In 2020 IEEE 12th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM) (pp. 1-6). IEEE.

[17] Silva, D. L., de Jesus, K. L. M., Adina, E. M., Mangrobang, D. V., Escalante, M. D., & Susi, N. A. M. (2021, March). Prediction of Tensile Strength and Erosional Effectiveness of Natural Geotextiles Using Artificial Neural Network. In 2021 13th International Conference on Computer and Automation Engineering (ICCAE) (pp. 121-127). IEEE.

[18] Maulion Garduce, C., Laroza Silva, D., & Marcelo de Jesus, K. L. (2021, November). Prediction and Sensitivity Analysis of Shear Strength of Reinforced Concrete Beams with Deformed Hook Steel Fiber using Backpropagation Neural Network coupled with Garson's Algorithm. In 2021 The 5th International Conference on Advances in Artificial Intelligence (ICAAI) (pp. 17-22).

[19] Joh, H., & Malaiya, Y. K. (2014). Modeling skewness in vulnerability discovery. Quality and Reliability Engineering International, 30(8), 1445-1459.

[20] Rikhotso, P. M., & Simo-Kengne, B. D. (2022). Dependence structures between Sovereign credit default swaps and global risk factors in BRICS countries. Journal of Risk and Financial Management, 15(3), 109.

[21] Gunduz, M., & Sahin, H. B. (2015). An early cost estimation model for hydroelectric power plant projects using neural networks and multiple regression analysis. Journal of Civil Engineering and Management, 21(4), 470-477.

[22] Ahmed, A., Ali, A., Elkatatny, S., & Abdulraheem, A. (2019). New artificial neural networks model for predicting rate of penetration in deep shale formation. Sustainability, 11(22), 6527.

[23] Marashi, M., Torkashvand, A. M., Ahmadi, A., & Esfandyari, M. (2017). Estimation of soil aggregate stability indices using artificial neural network and multiple linear regression models. Spanish Journal of Soil Science: SJSS, 7(2), 122-132.

A Lightweight Meter Detection Method Based on Yolov5

Junren SHAO[a], Jianglong YU[a], Lei LONG [a], Tao YANG[a], Anyun SHI[a], Qingshi YANG [a], Ning WANG [b], Tianqing XIA[c] and Shuaitong ZHANG [d,1]

[a] *China Southern Power Grid Co., Ltd. Kunming Bureau of EHV Transmission Company, Kunming, China*
[b] *Operation and maintenance center of Information and communication, CSG EHV Power Transmission Company, Guangzhou, China*
[c] *CMCCSI Co., Ltd., Beijing, China*
[d] *North China Electric Power University, Baoding, China*

Abstract. With the deepening of industrial automation, a large number of edge intelligent devices are deployed in industrial meter detection. In view of the limited computing and storage capacity of these embedded devices, we propose a lightweight meter detection method. Our proposed method is based on the widely used Yolov5, the depthwise separable convolution and squeeze and excitation channel attention module are used to simplify the backbone and head of the network, and further prune the filters of convolution layers via geometric median. Finally, model parameters and floating-point operations are reduced to 0.250M and 0.687G on the premise of ensuring the effect of the meter detection.

Keywords. meter detection, lightweight, depthwise separable convolution, channel attention mechanism, filter pruning

1. Introduction

In the environment with electromagnetic interference, digital electronic meter are prone to failure. Considering the factors of anti-interference ability, production structure and cost, pointer meter is widely used in many fields of society. Additionally, due to the layout design of pipelines, many meters are in positions that are difficult to be observed by humans, and need to be recognized with the help of embedded devices such as UAV and robot. Laroca et al. applied convolutional neural network to automatic meter reading, but the method based on Fast-Yolo has a slight deficiency in accuracy[1]. He et al. used Mask-RCNN to detect the meters, but the model is complex and huge, and the inference is poor in real time[2]. Fang et al. used ResNet-18 as the backbone of Mask-RCNN to reduce the network volume and meter detection time[3]. Zhang et al. selected Yolo network for rough positioning, and then used SSD network for fine positioning of instruments[4]. Li et al. utilized Mobilenetv2 to simplify the network, but its complexity still needed to be processed by the server, and only one category of meter was tested[5]. These methods are limited to the backbone network proposed for other general datasets,

---

[1] Corresponding Author, Shuaitong Zhang, North China Electric Power University, Baoding, China; E-mail: zst9512@126.com.

and the model parameters and calculations are not optimized according to the difficulty of instrument data. Considering that most of CNN's architectures are application specific[6], we focus on redesigning the backbone structure and further verifying the reduced network capacity through channel pruning.

In this work, aiming at the problem of multi-class meter detection, we improve Yolov5[7-10] which has been proposed recently and proved to be generally effective in a variety of production environments, to ensure the accuracy and complexity of the model. Specifically, the main research contents are shown as follows. 1) We collect the meter dataset in the real production environment, and mark the bounding box position and category labels. 2) We improve the original Yolov5 structure by introducing depth separable convolution[11, 12] and squeeze and excitation channel attention module[13] to reconstruct the network backbone and head, which reduces the parameters and computation of the original network and enhances the feature extraction efficiency of network parameters. 3) For the improved Yolov5 model, we use the popular filter pruning via geometric median method[14] to automatically adjust the hyperparameters of the network channel according to the model training results, so as to obtain a more lightweight model and almost no influence on mean average precision.

2. Methodology

The research methods of this paper are mainly carried out in three parts. Firstly, the overall architecture of Yolov5 is analyzed and introduced, and then the structure of network parameter redundancy is located. Secondly, the backbone and head structure with large parameters are simplified through depth separable convolution and squeeze and excitation channel attention module. Thirdly, the number of redundant channels in the network is removed by filter pruning via geometric medium method, and the mean average precision of the model is restored by fine-tuning.

2.1. Yolov5 Network Architecture

Yolov5 is a recent version of Yolo architecture series, which is widely used in various object detection scenes. Compared with the previous Yolov4, the volume of network is reduced by nearly 90% in the Yolov5. Therefore, it can be deployed to some devices with relatively limited resources. According to the difference between the number of feature extraction modules and internal convolution layer channels, Yolov5s, Yolov5m, Yolov5l and Yolov5x are derived by the complexity of the model from low to high.

Taking Yolov5s as an example, the specific structure is shown in Figure 1. The network architecture includes backbone and head parts. The backbone is mainly responsible for extracting multi-scale image features, and the head detects objects of various sizes on three type of feature maps (80×80, 40×40 and 20×20) to obtain information of bounding box (x: horizontal coordinates, y: vertical coordinates, w: width, h: height, conf: classification confidence, cls: classification category).

2.2. Improved Network Architecture on Backbone and Head

The original Yolov5 is designed based on the large-scale object detection dataset—coco, which requires more model parameters to fit the data samples. Considering the meter

detection problem we solved, there are few types and quantities to be distinguished, so we can use less convolution channels to extract features.

In addition, we also use depth separable convolution composed of depthwise convolution (DWConv) and pointwise convolution (PWConv) to compress the model parameters and calculation, and construct the channel attention mechanism (Squeeze and Excitation module, SE) to further enhance the efficiency of model feature extraction. According to the experiment and experience, the layer by layer output channels of the improved backbone are set as 32, 32, 64, 64, 128, 128, 256 and 256, and the processing channels in head are also reduced to 32, 64 and 128, as shown in Figure 2.
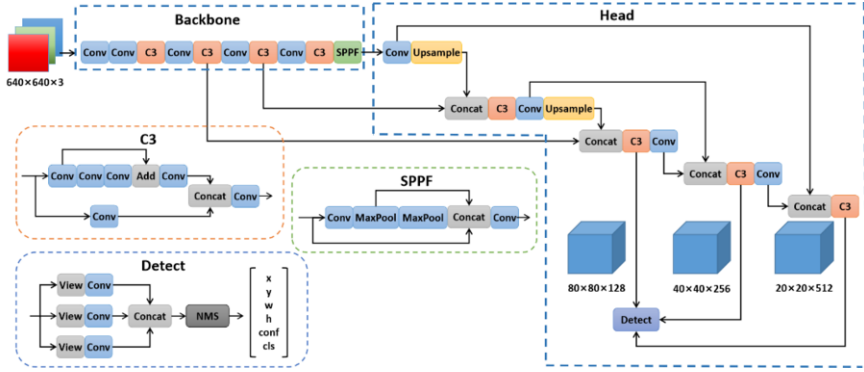
Figure 1. Original structure of Yolov5s.
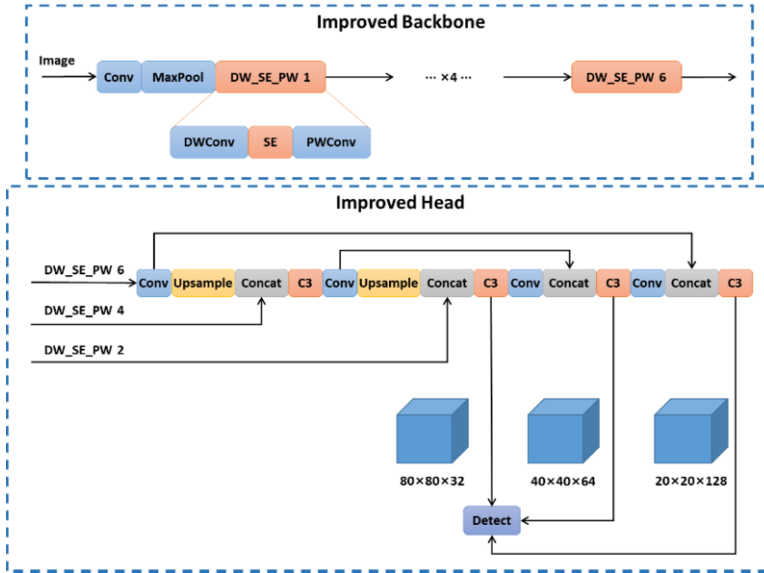
Figure 2. Improved structure of backbone and head.

2.3. Channel-pruned Network with FPGM

Some redundant parameters inevitably exist in the network structure designed by handcraft., so it is necessary to modify the network structure automatically in view of the

training results to remove redundancy. Filter pruning via geometric median is a popular structured pruning method, which removes redundant channels in the network convolution layers based on geometric median.

In detail, for a certain convolution layer, the parameter weight tensor of each filter is arranged in descending order based on 1-norm, and then several channels with the minimum sum of Euclidean distance accumulation between each filter will be removed. The number of channels pruned in each layer is divided into seven equal sections by the ratio we set. As the number of channels in the network increases layer by layer, we increase the proportion of pruning gradually, the basic features learned from shallow convolution can be retained when pruning as many redundant channels as possible. For example, our model has 52 convolution layers divided into seven parts: 1-8, 9-15, 16-23, 24-30, 31-38, 39-45 and 46-52. The pruning rates of each segment are about 0.05, 0.1, 0.15, 0.2, 0.25, 0.3 and 0.35 respectively. Since the number of segments cannot be divided by 7 evenly, the proportion of each segment increases or decreases slightly to maintain an average of 20%.

3. Experimental results and analysis

3.1. Dataset

Deep Learning algorithms can obtain a great degree of perfection in front of large datasets[15], so we collect numbers of meter data from the transmission lines of China Southern Power Grid. The data is manually cleaned by multiple professional, marked the rectangular frame coordinate value of the existing object, and labeled into six categories, including five categories: thermometer square, thermometer circle, lightning arrester, oil level gauge and SF6 meter. These images constitute our experimental dataset, of which 4364 are used for training and 181 for testing.

3.2. Related Details

The main details of the experiment include the augmentation method for expanding the amount of data, the software and hardware configuration for training, and the complexity and accuracy metrics for evaluating the model.

Like Yolov5, we adopt mosaic method[16], which uses four pictures to splice through random scaling, random clipping and random arrangement, so as to enrich the dataset and greatly improve the training speed of the network.

All programs are based on pytorch1.7 framework and accelerated model training through NVIDIA Geforce RTX 2080s. During routine training, 300 epochs are trained by cosine annealing algorithm[17], and then 100 epochs for finetuning after pruning.

In terms of evaluating the performance of the model, on the one hand, the complexity of the model is measured by the amount of parameters and floating point operations (FLOPs), and on the other hand, the accuracy of the model is evaluated by precision, recall and mean average precision (mAP), as shown in formula 1-4.

$$AP = \sum_{i=1}^{n-1} (Recall_{i+1} - Recall_i) \cdot \max_{j \geq i} (\Pr ecision_j)$$

(1)

$$Precision_i = \frac{TP_i}{TP_i + FP_i}$$

$$(2)$$

$$Recall_i = \frac{TP_i}{TP_i + FN_i}$$

$$(3)$$

TP_i, FP_i and FN_i respectively represent the number of ground truth IOU more than 0.5, less than 0.5, and the number that is wrongly identified as other categories in the top i bounding boxes of the model prediction on a single meter category. The IOU is the ratio of the intersection and union area of bounding box and ground truth, which is defined as follows:

$$IOU_j = \frac{S_{Boundbox}(k) \, \mathrm{I} \, S_{Groundtruth}(k)}{S_{Boundbox}(k) \, \mathrm{U} \, S_{Groundtruth}(k)} \quad (k \le i, k \in N^+)$$

$$(4)$$

3.3. Results Analysis

Table 1 shows the detection results of the final model we proposed. It can be seen that our model can achieve a precision and recall close to 1 on five categories of test samples. It is worth noting that the simplified model can still accurately locate almost all the samples to be tested, which can meet the needs of our real production environment.

Table 1. Experimental result of the proposed method on different classes.

Class	amount	Precision	Recall
thermometer square	30	0.933	0.933
thermometer circle	32	1.000	0.989
lightning arrester	55	0.979	1.000
oil level gauge	19	0.986	1.000
sf6 meter	45	0.964	0.978
all	181	0.972	0.980

In order to intuitively show the effect of the model and explain the feature information learned by the model as much as possible, we visualized the detection results of samples and gradient-weighted class activation mapping (Grad-CAM)[18]. As shown in Figure 3, the proposed model accurately predicts the position and category of the meter, and the regions of interest concerned by the model are concentrated in highly discriminative positions.

Further, in order to show the lightweight degree of the proposed model, we enumerate the differences between the original Yolov5 and our improved and pruned model in terms of parameters and FLOPs. As shown in Table 2, the network parameters after improving the backbone and head structure are reduced by nearly 18 times, and the network complexity after pruning is further reduced by more than 20 times with almost no loss of mAP. It is worth noting that compared with Yolov5 architecture of other backbone networks (ResNet-18, VGG-16 and MobileNet), we achieved a balance between model complexity and accuracy by decomplacing conventional complex convolutional operations through depthwise separable convolution and removing unnecessary model weights through channel pruning. It can also be seen from Figure 4

that compared with the original high parameter network, our improved and pruned model is only slightly different in object location and confidence, which is enough to meet the detection requirements, and proves the effectiveness of the proposed method.
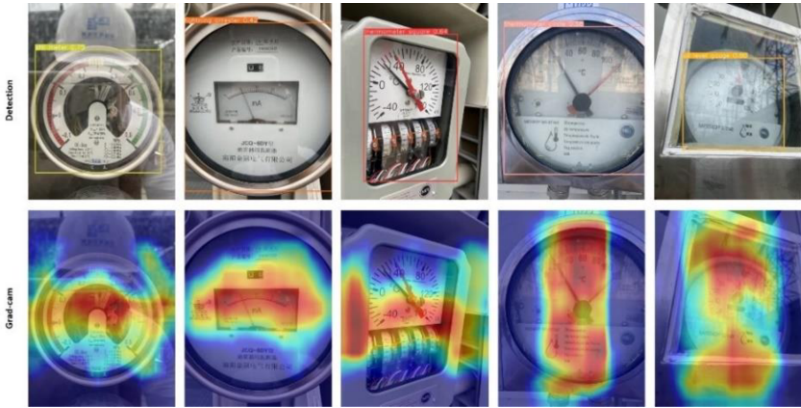
Figure 3. Detection and grad-cam results on our improved & pruned Yolov5.

Table 2. Comparison of model complexity and precision.

Model	Parameters (M)	FLOPs (G)	mAP
Yolov5s	7.033	15.980	0.993
Yolov5s-ResNet18	11.402	30.238	0.996
Yolov5s-VGG16	14.961	251.129	0.997
Yolov5s-MobileNet	3.490	3.488	0.991
Improved Yolov5	0.393	0.926	0.989
Improved & Pruned Yolov5	0.250	0.687	0.987
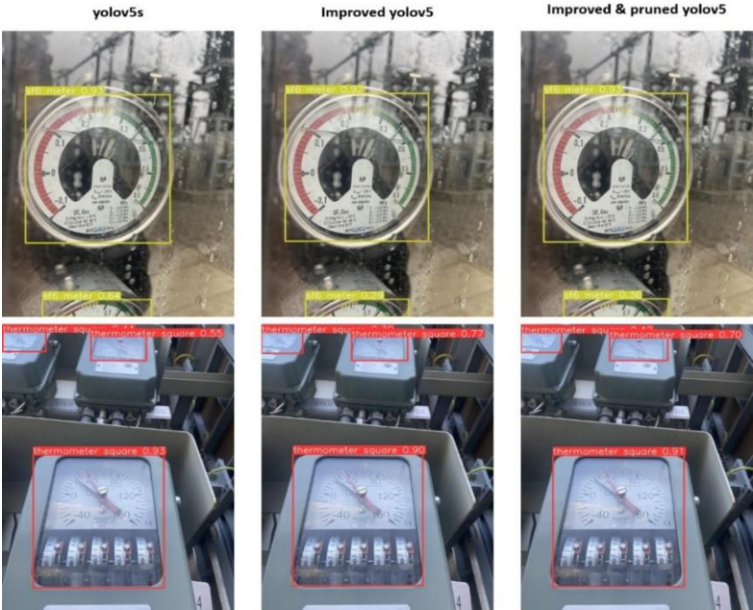
Figure 4. Comparison of detection effects of different models.

4. Conclusion

Aiming at the problem that resource constrained devices cannot efficiently detect meters in the real environment, we improve the structure of backbone and head based on Yolov5 architecture, greatly reduce the amount of network parameters and flops, and further remove the redundant channels in the model designed by handcraft through structured pruning method. Compared with the original network, our method reduces the complexity by more than 20 times, and can accurately locate the instruments. In the future, we will continue to collect more relevant data and study more advanced structures to comprehensively improve the detection quality and efficiency of the model.

References

[1]   Laroca R, et al. Convolutional neural networks for automatic meter reading. Journal of Electronic Imaging, 2019 Feb;28(1):13‑23.

[2]   He P, et al. A value recognition algorithm for pointer meter based on improved Mask-RCNN. 2019 9th International Conference on Information Science and Technology; 2019 Aug 2-5, Hulunbuir, China: IEEE. pp. 108-113.

[3]   Fang Y, Dai Y, He G, et al. A mask RCNN based automatic reading method for pointer meter. 2019 Chinese Control Conference; 2019 Jul 27-30, Guangzhou, China: IEEE. pp. 8466-8471.

[4]   Zhang X, Lu Y, Zhang X, et al. Research on Detection and Recognition of Pointer Instrument Based on Lightweight Network. Proceedings of the 2020 International Conference on Aviation Safety and Information Technology;2020 Oct 14-16, Weihai, China: ACM. pp. 301-306.

[5]   Li Q, et al. GIS Room Autonomous Inspection System Based on Multi-rotor UAV. 2021 International Conference on Electrical Materials and Power Equipment; 2021 Apr 11-15; Chongqing, China: IEEE; pp. 1-4.

[6]   Patel C, Bhatt D, Sharma U, et al. DBGC: Dimension-based generic convolution block for object recognition. Sensors, 2022, 22(5): 1780-1804.

[7]   Yan B, et al. A real-time apple targets detection method for picking robot based on improved YOLOv5. Remote Sensing, 2021 Apr;13(9): 1619-1641.

[8]   Zhou F, et al. Safety helmet detection based on YOLOv5. 2021 IEEE International Conference on Power Electronics Computer Applications; 2021 Jan 22-24; Shenyang, China: IEEE. pp. 6-11.

[9]   Zhao J, et al. A wheat spike detection method in UAV images based on improved YOLOv5. Remote Sensing, 2021 Aug;13(16), 3095-3110.

[10]   Wen P, et al. Research on early fire detection of Yolo V5 based on multiple transfer learning. Fire Science and Technology; 2021 Jan;40(1): 109-112.

[11]   F Chollet. Xception: Deep Learning with Depthwise Separable Convolutions. 2017 IEEE Conference on Computer Vision and Pattern Recognition; 2017 Jul 21-26; Honolulu, United States: IEEE. pp. 1800-1807.

[12]   Howard, et al. Mobilenets: Efficient convolutional neural networks for mobile vision applications. arXiv preprint arXiv:1704.04861. 2017; 1-9.

[13]   Hu J, et al. Squeeze-and-excitation networks. Proceedings of the IEEE conference on computer vision and pattern recognition; 2018 Jun 18-22; Salt Lake City, United States: IEEE; pp. 7132-7141.

[14]   He Y, et al. Filter pruning via geometric median for deep convolutional neural networks acceleration. Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition; 2019 Jun 15-21; Los Angeles CA, United States: IEEE; pp. 4340-4349.

[15]   Vasoya S, Patel N, Ramoliya D, et al. Potentials of Machine Learning for Data analysis in IoT: A Detailed Survey. 2020 3rd International Conference on Intelligent Sustainable Systems; 2020 Dec 3-5: Thoothukudi, India: IEEE; pp. 291-296.

[16]   Bochkovskiy A, et al.. Yolov4: Optimal speed and accuracy of object detection. arXiv preprint arXiv:2004.10934. 2020; 1-17.

[17]   Loshchilov I, et al. Sgdr: Stochastic gradient descent with warm restarts. arXiv preprint arXiv:1608.03983. 2017; 1-16.

[18]   Selvaraju R, et al. Grad-cam: Visual explanations from deep etworks via gradient-based localization. Proceedings of the IEEE international conference on computer vision; 2017 Oct 22-29; Venice, Italy: IEEE; pp. 618-626.

Applications of GMM-HMM Acoustic Model in the Immersive Foreign Language Learning

Jianghui LIU[1], Zitong WENG and Yiming ZHONG
Guangdong University of Foreign Studies, Guangzhou, China.

Abstract. This research presents an immersive oral English teaching mode by combining optimized GMM-HMM、VR technology with immersive learning theory, which enables learners to learn English in a real context with .This model can cultivate learners' cultural awareness and enhance their output ability in an effective way, making them achieve self-innovative development in the process of independent English learning. Informed by the current development of VR technology and English teaching through literature research, this study centers on the designs of immersive VR teaching models. It presents some practical experience by undertaking comparative research which was implemented based on immersive VR teaching and multimedia teaching. This study aimed to facilitate the trend of combining information technology and education.

Keywords. Optimized GMM-HMM acoustic model, immersion, VR, foreign language learning

1.Introduction

VR (Virtual Reality) information technology, also known as Virtual Reality simulation information technology, is a combination of computer science, sensor technology and performance Technology. In the virtual space formed by computer science, users can use head-mounted displays for real-time control, move freely in this space, and interact with the virtual environment with the help of multi-sensory channels such as sight, hearing and touching [1]. In recent years, with the rapid development of science and technology, virtual reality technology has been applied to many fields. Among them, the combination of VR technology and education is now a development direction with broad prospects [2-3].

In college, English teaching usually focuses on students' language application ability, but the expressions can only be trained and improved in the real environment of life. However, at present, many students are generally accustomed to the exam-oriented education mode in high school, and their oral output skills are relatively weak. In universities, the interaction between teachers and students in large classes is often very limited, and students have few opportunities to speak and practice English. The

---

phenomenon of "mute English" in class will further reduce students' interest in English learning. It is difficult for students to speak English at the beginning and improve their practical communicative ability.

In view of this situation, it is necessary to combine virtual reality technology with oral English teaching and give full play to the advantages of VR's "3I" characteristics, namely Imagination, Interaction and Immersion [4]. Teachers can teach by using virtual reality technology to construct real situations where students can get the feeling of "being on the scene", so as to strengthen language training and teaching of expression.

2. Research background

Immersive classroom teaching is a teaching method that emphasizes the use of the second language as the teaching language, that is, learners are "immersed" in the target language environment [5]. It originated in the 1960s in The United Kingdom. At that time, English and French were the official languages of the United Kingdom. However, due to the sharp increase of the immigrant population in the United Kingdom, the number and demand of learning and using English gradually increased, while French was the opposite. Based on this, the federal government took measures to improve the state of French education, which also led to the birth of immersion. After the success of immersion teaching in the UK, it has been used for reference by many countries and regions [6], which has greatly promoted the development of bilingual education.

In 1996, China launched a project on immersion English teaching, comprehensively reforming the original English teaching methods. On the basis of the previous teaching mode of English grammar, colleges and universities provide more opportunities for English output, hoping to improve students' English application ability and improve the overall English level. Immersion English teaching mode requires students to completely "immerse" themselves in the learning environment of the target language, so as to promote students to develop English thinking habits in a relatively short time, so as to achieve flexible use of English [7].

To achieve immersion learning, it is best to let students really enter a situation close to real life to feel and experience [8]. However, due to practical problems such as time, cost, distance and safety, it is difficult to reproduce the whole scene in the actual teaching process. The application of VR technology creates possibilities for immersive English teaching [9]. Immersion English enables learners to closely relate theory to reality after learning it. In the virtual reality learning environment, learners no longer only memorize and recite monotonously, but on this basis enhance the full application of theoretical knowledge in the real situation. The precise simulation and real-time interaction of VR skills can affect the quality of classroom teaching [10][11].

3.VR Immersive Oral English Learning System based on optimized GMM-HMM Acoustic Model

The generation process of the optimization of GMM-HMM acoustic model is shown in Fig. 1.
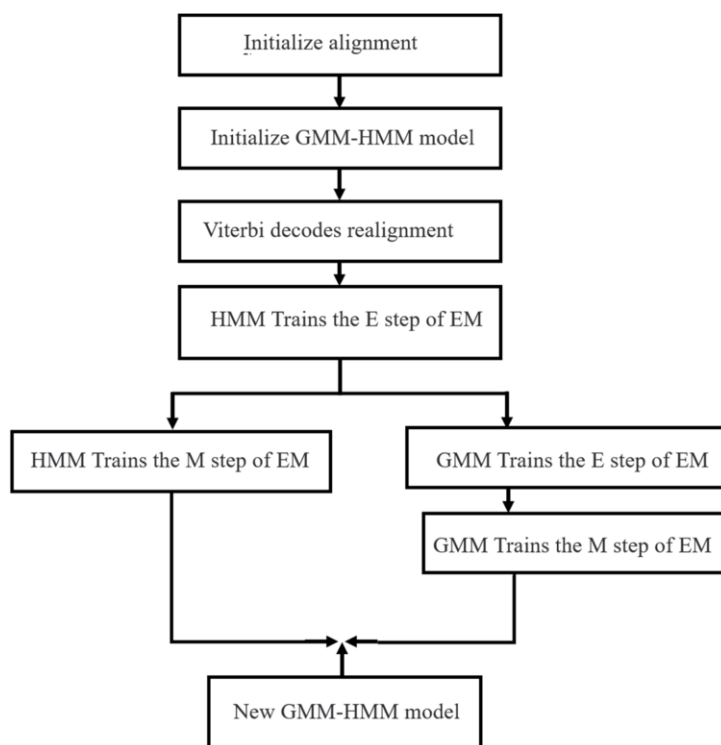
Fig. 1 Optimization of GMM-HMM acoustic model

The system will use the Viterbi training method (based on EM algorithm), which needs to explicitly input the state of each frame, and use marked data to update the parameters of GMM. Under this algorithm, it can run faster, but the performance of the model has no obvious loss.

- Model initialization. To carry out the training of HMM model, model parameter is taken to make $P(O \mid \lambda)$ local maximum values. Hence, choose a good initial model, to make the local maximum of parameters and global great closer, eventually improve the overall effect of the model.
- Then explicitly input the state of each frame and obtain the state number of each frame as the training label. Firstly, the state sequence of the trained speech can be obtained, and a state graph can be obtained, which gives the state sequence of the trained speech, and then the alignment is completed through the decoder.
- Finally, conduct model training using three-tone submodel training. When designing modeling units, we should not only consider the central phoneme itself, but also consider the context phoneme where the phoneme is located, which is the context dependent acoustic model, namely the three-tone submodel. In actual scenes, there may be coarticulation, and the actual pronunciation of phonemes may be affected by neighboring and similar phonemes, or may be changed due to different positions in sentences. Therefore, in order to improve the performance of speech recognition system, a more realistic three-tone submodel is used for modeling.

ER algorithm:

Input: observation data x= (x1,x2... , xm), the joint distribution $p(x, z|\theta)$, conditions of step-by-step $p(z|x, \theta)$, the largest number of iterations J

- Randomly initializes the initial value of the model parameter θ^0
- For j from 1 to J, the EM algorithm iteration starts:

a) E step: calculate the conditional probability expectation of the joint fractional steps:

$$Q_i\left(z^{(i)}\right) = P\left(z^{(i)}\middle|x^{(i)}, \theta^j\right) \qquad (1)$$

$$L\left(\theta, \theta^j\right) = \sum_{i=1}^{m} \sum_{z(i)} Q_i\left(z^{(i)}\right) \log P\left(x^{(i)}, z^{(i)}\middle|\theta\right) \qquad (2)$$

b) M step: maximize $L\left(\theta, \theta^j\right)$, obtain θ^{j+1}:

$$\theta^{j+1} = arg\max_{\theta} L\left(\theta, \theta^j\right) \qquad (3)$$

c）If θ^{j+1} converges, the algorithm ends, otherwise go back to step a) for step E iteration.

Output: model parameters θ

4. Experiment and Results

4.1 Design

Two different teaching modes are defined as independent variables, namely immersive VR teaching mode and traditional multimedia teaching mode. The differences and similarities between immersive VR teaching mode and traditional multimedia teaching mode are investigated.

The primary objective of this study was to determine whether immersive VR English teaching (independent variable) would improve learners' oral English. The hypothesis is that compared with the control group, oral performance will be significantly improved due to the application of immersive VR experience in the experimental group.

Taking into account these facts, the following primary research hypotheses were formulated:

Hypothesis 1. Learners who had immersive VR experience during the English course had higher spoken English fluency than those who did not.
Hypothesis 2. The oral English accuracy of learners who had immersive VR experience during the English course was higher than that of learners who did not.

A secondary goal of the study was to track participants' emotional state after the intervention. The secondary dependent variables were measured by two scales - the learning motivation questionnaire and the English Learning Anxiety Scale.

Hypothesis 3. The learners who got immersive VR experience during the English course were more motivated to learn English than those who did not.

Hypothesis 4. Learners who had immersive VR experience during the English course had lower anxiety in English learning than those who did not.

4.2 Participants

A total of 30 sophomore undergraduates from a university in Guangdong province participated in the study. Their average age was 20. One class was assigned to the experimental group (Class A) and the other to the control group (Class B). Each of them consists of 15 students. None of the participants had prior experience using immersive VR in English classes. For computer-assisted language learning, undergraduates often read audio files or watch video files played by their teachers as they practice their spoken English skills.

4.3 Materials

Take Unit 1 "Getting to Places" as an example. This Unit mainly introduces the transport system and landmark location of London, involving historical background knowledge, spatial direction and other related vocabulary and expressions. In traditional Chinese teaching, teachers only introduce various landscapes to students with the help of pictures in books and PPT, and teach relevant background and professional knowledge. However, students cannot truly feel exotic scenery and humanistic scenery, and it is difficult to form a deep understanding of "Double-Decker", "Minicab" and other British characteristic transportation vehicles, let alone form a deep understanding of a more abstract concept of orientation in a completely unfamiliar city.

4.4 Instruments

After the students in the experimental group and the control group completed the weekly course learning, they were required to record a piece of audio composition according to the task assigned by the teacher (related to the theme of this unit), and the teacher scored according to the scoring guide.

4.5 Results

In general, through the comparison of test scores and scale results, the following findings are obtained: first, immersive VR teaching mode has a positive impact on students' oral performance, specifically in terms of improved language fluency, comprehension and maturity. Therefore, it can be inferred that immersive VR can improve the effect of English teaching; Second, immersive VR teaching mode can improve students' motivation for English learning. It can be inferred that immersive VR brings students multi-sensory stimulation and helps stimulate their interest in English learning. Thirdly, immersive VR teaching mode is helpful to relieve English learning anxiety of learners. Therefore, it can be inferred that students will feel more confident and safer when facing virtual characters, and thus use English more actively and boldly.

5.Conclusion

To sum up, immersive VR technology brings great possibilities for English teaching. The integration of virtual reality technology and English has created a new English teaching environment, which is helpful to solve the problem of context that has long puzzled English learners in China. The learning modes proposed in this paper can enable learners to experience and actively participate in real situational activities in a virtual way, further develop their discourse and logical thinking in real situational activities by using the professional English knowledge they have learned, practice boldly, and experience success in them. But at the same time, VR technology in the application of classroom teaching, still face many practical problems. VR technology to create a new model of classroom teaching is still only a prototype, there is still a large gap between imagination and improvement. In general. The application of virtual reality technology, especially immersion VR, in higher education is still not fully mature. Hardware facilities, application software resources, application environment teaching methods and evaluation and other application fields need to be further studied and discussed.

References

[1] Gardner, R.C., & Lambert, W.E. (1959). Motivational variables in second-language acquisition. Canadian journal of psychology, 13, 26-72.
[2] González C R, & Martín-Gutiérrez J, & Domínguez M G, et al. (2013) Improving spatial skills: An orienteering experience in real and virtual environments with first year engineering students. Procedia Computer Science, 25: 428-435.
[3] Aydogan H, Ata R, Ozen S, et al. (2014) A study of education on power transformers in a virtual world. Procedia -Social and Behavioral Sciences, 116: 3952-3956.
[4] Burdea G, & Coiffet P. (2003) Virtual reality technology, second edition. New York : John Wiley & Sons:3-4.
[5] Ke Ren. (2021). An Analysis of the Application of Immersion Teaching Method in Japanese Teaching. Journal of International Education and Development (9).
[6] PhD T. J. Ó Ceallaigh. (2016). Second Language Acquisition and Form-Focused Instruction in Immersion: Teaching for Learning. World Journal of Educational Research (2).
[7] Richardson, J. C., & Swan, K. (2003). Examining social presence in online courses in relation to students' perceived learning and satisfaction. Journal of Asynchronous Learning Networks, 7(1): 68-88.
[8] Grassini S, Laumann K, Rasmussen Skogstad M. (2020). The Use of Virtual Reality Alone Does Not Promote Training Performance (but Sense of Presence Does). Front Psychol, (11) : 1–17.
[9] Wang C, Lan Y J, Tseng W T, et al. (2019) On the effects of 3D virtual worlds in language learning–a meta-analysis. Computer Assisted Language Learning: 1-25.
[10] Jorge Bacca-Acosta, Julian Tejada, Ramon Fabregat, Kinshuk, Juan Guevara. (2021) Scaffolding in immersive virtual reality environments for learning English: an eye tracking study, Educational Technology Research and Development, 2021.
[11] Lan, Y. J. 2020. Immersion, Interaction and Experience-oriented Learning: Bringing Virtual Reality into FL Learning. Language Learning & Technology(1) :1-15.

Traditional Chinese Medicine Information System Using Classification and Clustering Algorithms

Weiwei QU[a,1], Marifel Grace C. KUMMER [b] and Delong CUI[c]

[a] *Shandong College of Traditional Chinese Medicine, Yantai, China*
[b] *St.Paul University, Philippines*
[c] *College of Computer and Electronic Information, Guangdong University of Petrochemical Technology, Maoming, China*

Abstract. The main function of Chinese medicine decision support system is to cluster Chinese medicines based on K-means (cluster Chinese medicines with similar properties into groups, so as to discover new properties of Chinese medicines, which can be referred to during drug use). The other is to classify Chinese medicines by Bayesian classification. The purpose of classification is to find the traditional Chinese medicine that can be used as nutritious food, or to find the traditional Chinese medicine with food and nutritional properties. Firstly, the traditional Chinese medicine with known food properties is used as the sample, and the Bayesian algorithm is used for learning and training. Then, the training model is used to analyze the new traditional Chinese medicine, so as to analyze whether a certain traditional Chinese medicine has the properties of nutritional food. Other functions include traditional Chinese medicine basic information management, traditional Chinese medicine data collection, traditional Chinese medicine data preprocessing, etc. After the operation of classification and clustering, the input data of traditional Chinese medicine will have more predictive values (mainly whether it has food nutrition or which traditional Chinese medicine can be divided into the same group), which can be used for reference by traditional Chinese medicine practitioners.

Keywords. Traditional Chinese medicine, classification, cluster, information management

1. Introduction

In this highly challenging and demanding world, data and technology are overwhelming. Data of all sorts that come from different sources are considered and processed accordingly. This happens in order to simplify every aspect of human life, such as communication, transportation, learning, and others. In this scenario, the Traditional Chinese Medicine College is not an exception in a technology-driven community. It is one of the many institutions where data and technology are used in countless ways.

---

[1] Corresponding Author: Weiwei QU, Shandong College of Traditional Chinese Medicine; E-mail: 735180699@qq.com.

According to Martins Ekor (2014) the use of herbal medicinal products and supplements has increased tremendously over the past three decades with not less than 80% of people worldwide relying on them for some part of primary healthcare. Ekor (2014) further stated that the use of herbal remedies has also been widely embraced in many developed countries with complementary and alternative medicines (CAMs) now becoming mainstream in the UK and the rest of Europe, as well as in North America and Australia. [1]

At present, many countries in the world rely on natural medicines in the development of new drugs. The signs show that Chinese medicine has not been rejected or treated as an alternative medicine in the international community, but it has been widely accepted and valued by the whole world. It can be predicted that Traditional Chinese Medicine will develop faster in the vast space in the 21st century. China's Traditional Chinese Medicine has been recognized by many consumers around the world. The World Health Organization (WHO) has put traditional medicine on the agenda and established 26 cooperation centers for traditional medicine in five continents at the same time. There is a growing international concern about Chinese herbal medicine.

The treatment of traditional Chinese medicine is mostly based on the experience of the doctor and the judgment of individual. The early prescriptions of traditional Chinese medicine are mostly preserved by word of mouth. This brings difficulty and challenges to the people in getting a doctor's advice. The inheritance of traditional Chinese medicine has always been carried out by teachers and apprentices, thus the authenticity and integrity of prescription of drugs will be reduced during its transmission.

With the deep development and wide application of information technology, especially on the application of big data analytics, data mining, artificial intelligence, and other technologies in various fields, traditional Chinese medicine administrators realized that there is a need for the college to adopt scientific and technological innovations. Thus, the combination of traditional Chinese medicine technology and the use of a modern technology will have a great impact in the development of the traditional Chinese medicines. Therefore, Shandong College of Traditional Chinese Medicine need to develop a system for teaching and learning to all the students and for public use. The developed system includes different features like classification, clustering, decision support and other features.

The developed system will classify and cluster the medicines according to year, efficacy, growth environment, type of diseases, and symptoms. Also, the system will provide a decision support to provide information to the users on how to use the traditional Chinese medicines and its treatment procedures. However, description of the disease with the prescription and corresponding treatment were not included as part of the decision support. This will be part of the enhancement of the system in the future.

2. Related Works

2.1 Information Management System

In "Independent Development of Laboratory Information Management System", was introduced by Li Yuan et al. (2021). [2]This was developed to realize the digitization, scientization, standardization and refinement of laboratory information management in the college. The system has established the laboratory electronic archives covering the laboratory scale, experimental modules, infrastructure, research projects, teaching arrangements and laboratory personnel, as well as a laboratory information query system with navigation function, and online reservation and approval of the laboratory. The status of laboratory information can be updated and checked at any time to improve the timeliness of laboratory management and conducive to the full utilization of laboratory resources. Ye Lixin (2020) introduced in his study "Design and Development of Information Management System for Neonatal Disease Screening in Dongguan City" that an information management system for neonatal disease screening in Dongguan City should be developed and constructed to realize information management of the whole process of neonatal disease screening in Dongguan City. [3]The development of information management system improves user experience and saves manpower and material resources. On the one hand, it improves the accuracy, timeliness, and continuity of data management. It reduces the occlusion of information and enhances the communication and sharing between information, especially for the information management of classification and clustering of traditional Chinese medicine, especially for the research of this system and the management of traditional Chinese medicine information, which plays a huge role in promoting and promoting the process and influence of traditional Chinese medicine in medical treatment to some extent.

2.2 Classification Algorithm

Zhang Hongli (2020) discussed in his study "Research on some Problems of Classification Mining Based on Experiments", that classification is one of the key contents in the field of data mining. The main goal of classification mining is to train a model with strong generalization ability in the sample set of known categories and to have an accurate prediction of new data.[4] Zuoxiang (2017) cited in his study "An Effective Multi Relationship Bayesian classification Algorithm" that traditional data mining algorithms need physical connection when dealing with multi relationship, so there is a problem of low efficiency. [5]The classification algorithm represented by Bayesian algorithm can quickly classify the data information in the database especially for the complex information of traditional Chinese medicine which can improve the efficiency of information analysis and save the labor cost.

3. Research Design

3.1 Architectural Design
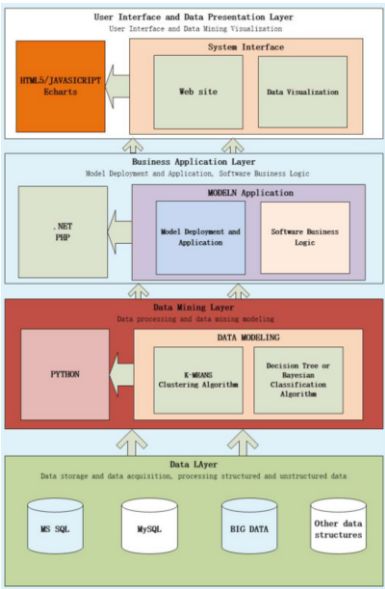
Figure 1. System Architecture Design

Figure 1 is the system architecture design. The system architecture is divided into four layers.The system will be composed of data acquisition, data preprocessing, clustering, classification, and with decision support.

The first layer is the bottom layer, which belongs to the data layer. It is responsible for data collection and data storage. The technologies used include Sql server Chinese medicine characteristics is multifaceted, including information about medicines, information about prescriptions, and information about syndromes and symptoms. The relationship between them is ever-changing and intricate. Therefore, designing system data storage is a challenging task. In line with the principle of reducing system redundancy and facilitating rapid system processing, as well as flexibility and scalability, the database designed for this system can be divided into five categories according to the different uses of these tables: basic tables, preprocessing table, user input table, output table, temporary table.

The second layer of the system is the data processing and data mining layer, responsible for data mining model, the technology used is Python, the algorithm used is k-means clustering algorithm, decision tree or Bayesian classification algorithm.

The third layer of the system is the business application layer, responsible for data model deployment, data model application, and software business logic. The technology used is application system development technology, such as .NET or PHP.

The top layer of the system is the interface layer and data display layer, responsible for user operations The interface and data mining display use technologies such as HTML5/JAVASCRIPT.

3.2.K-means Clustering Model Training

The researcher use cluster and K-Means package in Python sklearn library for clustering model training.
Let's first draw a scatter matrix. As shown in the figure 2.
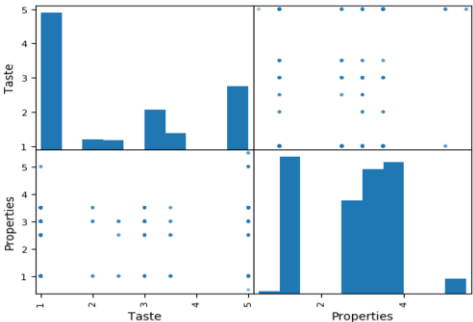
Figure 2. Scatter matrix diagram and Scatter plot of clustering

As can be seen from the Figure 2 above, there is no linear relationship between Taste characteristics and Properties.
This is a scatter matrix diagram. It can be seen from the figure that the Clustering algorithm divides the training set of traditional Chinese medicine into 4 categories.
Next, the researcher continues to draw the scatter diagram of clustering to visualize the clustering features. As shown in the Figure 3 below.
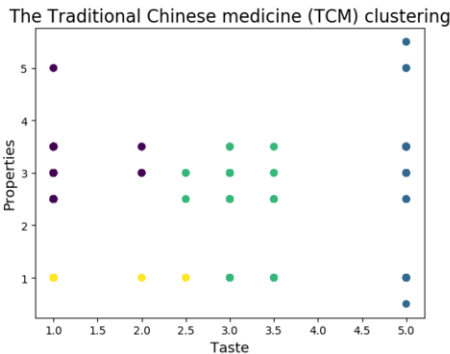
Figure 3. Scatter Plot of Clustering

The Figure 3 above is the scatter diagram of k-means clustering results. As can be seen from the color classification and clustering classification in the figure, data can be clustered into 3 categories. It can be seen from the figure that the Clustering algorithm divides the training set of traditional Chinese medicine into 4 categories. Among them,

TCM with Taste attribute value of 2.5-3.5 and Properties attribute value of 2.5-3.5 are classified as one category. The rest of the classification can be seen in the different colors of the scatter plot.

However, since traditional Chinese medicine uses discrete value description to describe the properties of traditional Chinese medicine, k-means needs to use continuous value. Although the researcher performs data conversion, the clustering result is still not ideal, because the classification between classes is not very obvious.

3.3.Bayes Algorithm was Used to Train Classification Model

Bayes classification algorithm can be divided into many kinds, such as naive Bayes classification, Gaussian Bayes classification, Bernoulli Bayes classification and so on. Naive Bayes is suitable for the classification of discrete eigenvalues. If the eigenvalues are continuous, Gaussian Bayes or Bernoulli Bayes classification algorithm is adopted. Bernoulli Bayes classification is used here.[6]

3.4.Use Python to Train Data

K-fold cross validation can make the training result more reliable. The training results are represented by the confusion matrix in the figure 4 below.
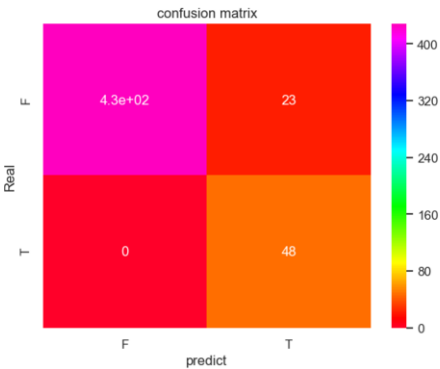
Figure 4. Confusion Matrix Grap

At the same time, the printed explanatory chart is shown in Figure 5.
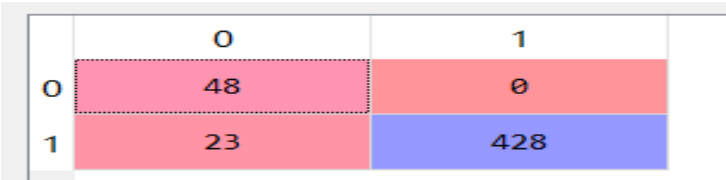
Figure 5. Interpretation Chart

As can be seen from the confusion matrix diagram, the Y axis REAL is the Real classification, and the X axis PREDICT is the predicted classification. As can be seen from the matrix diagram, the real category is F, and there are 428 predicted categories

of F. The true category is F, but the predicted category is T, 23. The true category is T, but the predicted category is F, 0. The true category is T, and the predicted category is T, is 48. This prediction accuracy is quite high.

4. System implementation

The implementation of the application system mainly uses ASP.NET language +Visual Studio 2019 development tools. In the data analysis and data mining model establishment stage, we use python language, python language in data analysis and data mining has better advantages, but the development of applications, platform level Web applications, using ASP.NET has greater advantages, therefore, our software architecture is designed for ASP.NET+Python hybrid programming. That is to say, data analysis and data mining layer, using Python language, used for the establishment of the model, after the establishment of the model, the integration of model deployment into ASP.NET applications, data mining, data analysis of the integration of operations, make ASP.NET information system with data mining function.

Figure 6. System Login Interface

After entering the login page, enter the user's name, password, and verification code to log in to the system. Test user login name is manager@gmail.com The password is manager

Figure 7. The Import Data Page

The import data page is used to import data directly from a database or other data source. The data of major Traditional Chinese medicine has been imported in the page

with a list of traditional Chinese medicine data, including all kinds of information of traditional Chinese medicine. For this data import module of the TCM information is presented as data analysis. It is also a general understanding and exploration of data to find out whether there are problems with the data.

5. Conclusion

Based on the results of this study, the following conclusions are drawn:
Chinese medicine classification and clustering system is an effective Chinese medicine information management system. When it comes to traditional Chinese medicine analysis, information preservation and information retrieval, the system provides fast and convenient access to traditional Chinese medicine data. In addition, the development of this system provides an innovative scheme for introducing homology of medicine and food, that is, the application of traditional Chinese medicine in diet. It provides a new idea for the introduction and development of traditional Chinese medicine globalization. Therefore, the system is worth using because the features and functions of the developed system roughly conform to the ISO/ iec25010 software quality standard.

Acknowledgements

References

[1] Martins E . The growing use of herbal medicines: issues relating to adverse reactions and challenges in monitoring safety[J]. Frontiers in Pharmacology, 2013, 4:177.
[2] Li Yuan, Zheng Kaiyuan, Shi Qin, & Luo Jinwu. (2021). Independent development of laboratory information management system. Technology horizon.
[3] Ye Lixin, Zhong Yuhang, Zhong Chaozhen, Chen Jinguo, & Huang Xiaoling. (2020). Design and development of neonatal disease screening information management system in Dongguan city. Chinese Journal of Medical Innovation, 17(18), 6.
[4] Hongli Zhang. (2020). Research on some problems of experimental classification mining. (Xi 'an University of Technology, DISSERTATION).
[5] Deng Zuoxiang, TU Fang. An efficient Multi-relation Bayesian classification algorithm [J]. Microelectronics & Computer, 2017, 34(7):5.
[6] Qin HUAIqiang. Research and application of several improved Naive Bayes classification algorithms [D]. Shandong University of Science and Technology, 2018.

Impact of Fintech on Islamic Bank Performance in Malaysia: Descriptive Study on Fintech

Manal Rickinghall[1]
Ph.D. Aspirant, Segi University, Malaysia

Abstract. This paper aims to evaluate the impact of Islamic FinTech innovations on Malaysia's banks' performance by utilizing the eighteen regional commercial banks that started Islamic banking in Malaysia. The data is from 2005 - 2020 with four hundred and seventy observations. Multivariate regression has been used to evaluate the research questions empirically. This research is the first to statistically evaluate the Islamic fintech innovation impact on the bank's performance in Malaysia. Furthermore, research on financial metrics is presented thoroughly for the years 2005-2020. We have contributed to the Islamic FinTech era with the following findings: (i) The Islamic FinTech has a positive effect on the bank's performance in Malaysia; (ii) The Islamic FinTech has also positively affected the banks' income; (iii) The impact of Islamic FinTech on economic performance was more substantial for the small-banks compared with large-banks; (iv) In terms of balance sheet debts, small banks' funds of money market are positively influenced by the application of Islamic FinTech; (v) In terms of consumer loan repayments to the small banks have been positively impacted by the app of Islamic FinTech; (vi) The per capita GDP does have a good impact on *ROE* of banks; (vii) Penetration rates of Islamic banking has positively impacted bank' return on assets and equity.

Keywords. Innovations of Fintech, bank performance, apps of Islamic FinTech, Malaysia, theories of Technological Innovation.

1. Introduction

Malaysian Banking sector is voluminous in terms of services [1]These services could be established based on the novel, inventive concepts, or they may be obsolete but supplied in the latest trend to simplify the transaction processes and expand client' reach to the economic facilities [2]. This has led Malaysian Banking sector to have dedicated Islamic FinTech as a new trend, whereby all Islamic banking services are offered through the new technology. As a result, Islamic FinTech is playing an essential part in the growth of the banks in Muslim countries. As Malaysia is an Islamic country with a 61.1% population of practicing Muslims, so the overall sentiment of the country is towards Islamic practices [3]. Generally, the traditional banking mechanism in the Muslim community is considered forbidden or at least Makrooh [4]. In Malaysia, the concept of Islamic banking was introduced in 1963 when the PWSBH was established as a foundation for Muslims to save for Hajj expenses [5]. The first Malaysian Islamic

---

[1] Corresponding Author: Manal Rickinghall, Segi University, Malaysia; Email: bshanmug20@gmail.com

bank was publicly announced in 1983. Afterward, in 1993, merchant banks, commercial banks, and other finance corporations were granted Islamic banking services. However, it was compulsory to keep conventional and Islamic banking funds separate [6].

FinTech is about involving or injecting technology in financial proceedings. This could be in banking or any finance related services. The concept of mobile-banking is part of e-banking, whereas, the payment channel in mobile banking can be classified under FinTech [7]. Fintech is the new applications, processes, products, or business models in the financial services industry, composed of one or more complementary financial services and provided as an end-to-end process via the Internet[8]. Theory of technology and innovation describes about the meta-learning concept, and the concept of technological interdependence which are used to relate technology and innovation to strategic management [9]. And Islamic FinTech is about doing all that within the Shariah universe as defined by Polyzos [10].

Several studies have been done earlier about Malaysian banking industry. In fact, there are equivalent studies related to FinTech in Malaysia [7]. This respective research could be an extension for those researches. There are twenty-seven commercial banks in Malaysia, from which nineteen are traditional foreign banks, eleven investment banks, eighteen Islamic banks, and many other non-bank financial corporations [7]. The noticeable development in Islamic banking in the finance industry (FinTech) has created numerous possibilities. Islamic financial transactions have arisen to replace conventional banks [11]. Fintech innovation, particularly Islamic FinTech applications, has lately grown substantially in the digital era. There exists several theoretical and practical researches on the influence of Islamic FinTech on banks' performance all around the globe. However, empirical research on how Islamic FinTech applications affect overall [7] banking industry performance is still unknown, notably within Malaysia, where almost no empirical research exists. Furthermore, it is vital to examine the impact of Islamic FinTech on banking metrics in the fourth industrial revolution. In order to critically examine the overall impact, we have adopted the following research questions:

RQ 1. Does Islamic Fintech adoption affect all the indicators of finance across the banks?

RQ 2. Does Islamic FinTech adoption have additional fee revenue for the small-banks compared to large-banks?

RQ 3. Does Islamic FinTech adoption have different operational costs for the small-banks compared to large-banks?

RQ 4. Is there any more remarkable influence on the repayment of customer loans in small-banks than large-banks?

RQ 5. Does Islamic FinTech adoption have a more significant effect on the ROA and ROE of small banks than large banks?

In order to answer the above-mentioned questions, we have adopted the Theories of Technological Innovation and exploratory research methodology [12]. Multivariate regression has been used to answer the research regarding a relationship between various research variables concerning bank performance and Islamic FinTech

innovations [3]. Excel tools and STATA-14 are employed to conduct a multivariate regression framework. The ordinary least squares approach has been used to predict parameters in regression equations and independently assessed coefficients. The rest of the paper is organized in the following manner [8]. Section II explains the method of data collection and variables utilized in the research. Section III provides the results and analysis of the data. Section IV proved a comprehensive discussion on the research questions and the outcomes of the results. It concludes the research with the future directions [13].

2. Methodology of Islamic FinTech innovation' Evaluation

A. Dataset

We have utilized a range of various data for examining the impact of the Islamic fintech reform on the bank efficiency of eighteen Islamic banks in Malaysia from years 2005 to 2020 as follows:

- Balance sheets and revenue statements from 2005– 2020 were taken from the Central Bank of Malaysia [14].
- Annual reports from 2005 - 2020 are obtained from the websites of each bank [13].
- News and notifications from every bank's website detect Islamic FinTech activities, performance, and strategy[13].
- Guidelines and news clippings from the Central Bank of Malaysia website to detect legal restrictions controlling Islamic FinTech businesses, commercial banks, & the present situation of payments [14] .

B. Research Variables

The independent factors studied for innovation of FinTech include the era of the Islamic FinTech apps (MBA_AGE) [15], penetration rates of mobile (MPP_RATE), and GDP per capita (GDP_PC) [16]. The bank's performance is the outcome of the dependent variable [13]. This research examines 17 distinct financial variables, such as revenue stream, spending structure, profitability, and balance sheet design, like ROA, ROE given in Tab. 1.[16]

This paper employs multivariate regression using the Islamic FinTech tabular finance and banking data from 2005 to 2020. Many economic indicators are evaluated depending on each application stage.

3. Results and Analysis

Islamic FinTech years are recorded from 2005 - 2020. The console of the regression model is performed independently for a complete sample of eighteen banks' domestic trade throughout Malaysia (four hundred and seventy observations) from 2005 to 2020 [17]. An application of Islamic FinTech (MBA AGE) was employed for the

study's independent variables. In addition, the panel regression includes the extra independent study of *GDP per capita* variables and Islamic banking penetration rate to examine the effect of the market and macroeconomic factors.

Table 1. Summary of the Variables utilized for Analysis of Bank Performance

Variable	Description	References
NIC_ASS	Total Interest Income $\overline{\hspace{2cm}}$ *Total Assets*	[17]
FEIN_ASS	*Fee Income* $\overline{\hspace{3cm}}$ *Total Assets*	[1]
NEX_ASS	Total Interest Expense $\overline{\hspace{4cm}}$ *Total Assets*	[18]
SALA_ASS	Total Salaries $\overline{\hspace{3cm}}$ *Total Assets*	[19] [20]
CASH_ASS	Total Cash $\overline{\hspace{3cm}}$ *Total Assets*	[21][16]
SGA_ASS	*Total Selling General & Admin Exp* $\overline{\hspace{4cm}}$ *Total Assets*	[22]
SEC_ASS	*Total Securities* $\overline{\hspace{2cm}}$ *Total Assets*	[16]
LOAN_ASS	*Total Loans* $\overline{\hspace{2cm}}$ *Total Assets*	[5]
CONSLO_LO	*Total Consumer Loans* $\overline{\hspace{3cm}}$ *Total Loans*	[23]
COMLO_LO	*Total Commercial Loans* $\overline{\hspace{3cm}}$ *Total Loans*	[24]
Adj_ROA	The adjusted return on assets	[6]
NPL − LOA	*Non−* Performing Loans $\overline{\hspace{3cm}}$ *Total Loans*	[6]
DD_DEP	*Total Demand Deposits* $\overline{\hspace{3cm}}$ *Total Deposits*	[24]
DEPO_ASS	*Total Deposits* $\overline{\hspace{2cm}}$ *Total Deposits*	[25]
Adj_ROE	Return on equity	[26]
MM_DEP	*Money Market & Savings Account Deposits* $\overline{\hspace{4cm}}$ *Total Deposits*	[8]

Table 2. Research variables' analysis in the model of equation

Variables	Max	Min	Mean	Std_Dev
MBA_AGE	8	0	2.34	**2.143**
MPP_RATE	0.35	0.21	0.42	**0.06**
GDP_PC	3012	1564	2244.6	**233.412**
INEX_ASS	0.069	0.003	0.051	**0.011**
NIC ASS	0.121	0.042	0.076	**0.012**
CASH − ASS	0.032	0.007	0.007	**0.003**
COMLO_LOAN	0.384	0.254	1.76	**0.543**
CONSLO LOAN	0.876	0.976	0.789	**0.002**
Adj_ROE	26.37	0.08	9.89	**9.12**
DEPO_ASS	**0.963**	**0.461**	**0.996**	**0.090**

The Islamic Banking positively affected the whole sample's fee income ($FEIN. ASS$) at 0.067, including an adjusted R2 of 87%, as shown in **Fig. 1**. The fees of account-service, securities trading, foreign exchange, loan, and credit use are all part of fee income[13]. All the local and commercial banks in Malaysia with Islamic banking are classified into two groups based on their median asset size: small banks with under VND one hundred and fifty trillion in the assets and major banks with over VND one hundred fifty trillion in the assets [18]. At the asset side of balance sheets, Islamic FinTech has the most significant impact on consumer loans, $CONSLO\_LOAN$, 2. 74 (Fig. 2), with an adjusted R2 of 82% as Islamic FinTech applications are integrated into an increasing number of devices. As a result, consumer investments and loans are made easier [19]. The key conclusion is that Islamic banking did not affect interest revenue or interest expenditure in small and big banks [8]. However, Islamic baking increased small banks' fee revenue by 0.315, including an adjusted R2 of 56.2%, which answers the **RQ1**. Islamic FinTech applications had a negative impact on bank payroll and the SG&A expenditures of the small banks, which answers the **RQ2** on operational cost reduction [20]. The most critical result among variables came from consumer loans positively influenced by Islamic FinTech applications. Its impact was significantly more significant on the small banks with $CONSLO\_LOAN$ of 3.988 and adjusted R2 of 74.8%. That is the most significant coefficient, indicating that an annual rise in Islamic FinTech use would raise consumer loans of small banks by 4.28%, which answers the RQ3.
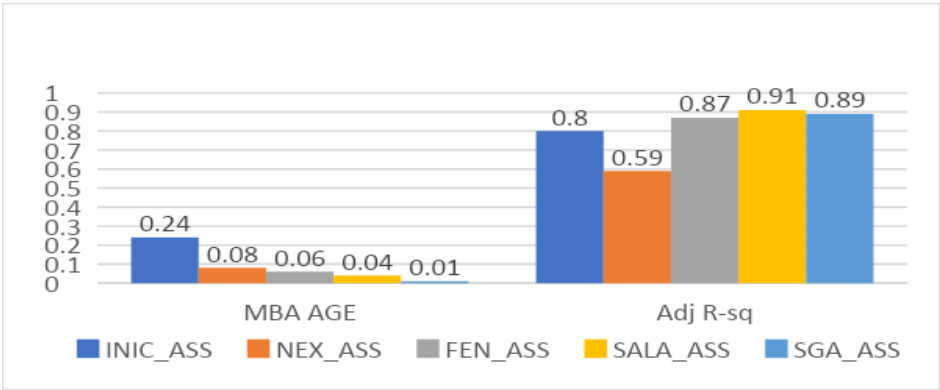
Fig 1. Effect of Islamic Banking on all banks' financial performance using variables from Income statements
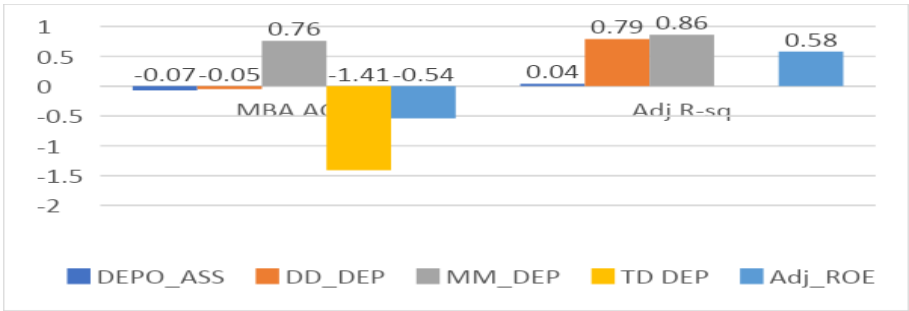
Fig 2. Effect of Islamic Banking on all banks' financial performance using variables from Assets side of Balance Sheet
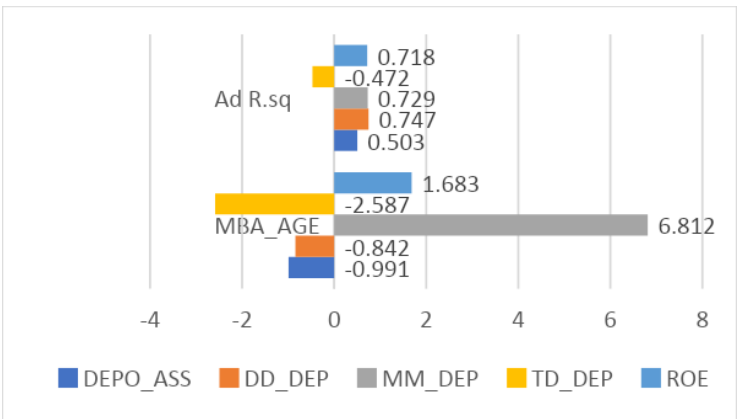
Fig 3. Islamic Banking effect on the small banks OLS method using Liabilities and Equity side

Overall, Islamic FinTech applications positively impacted securities assets and cash, and they had a positive effect on loan assets [27]. The banking application positively affected an adjusted ROA of significant banks, which was 0.026 (**Fig. 3**) less than the coefficients of small banks, which were 0. 20 (**Fig. 3**) answering the RQ4. Islamic banking had a negative impact on deposits assets of -3.179, including an adjusted $R2$ of 67% (**Fig. 4**). Islamic FinTech had a negative impact on adjusted ROE at 0.87, including an adjusted $R2$ at the 62% (**Fig. 5**). These findings show that the Islamic banking methods did not improve large banks economic performance, answering the RQ5 of more significant technological impacts on the small banks. The income statements of the large banks were highly unaffected, lending credence to the concept of Islamic banking's impact on the small banks [27].
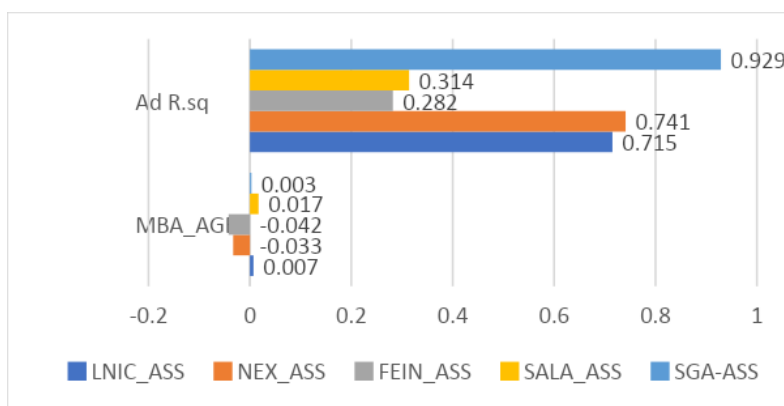
Fig 4. Islamic Banking effect on the large banks by using Income statement variables using OLS method
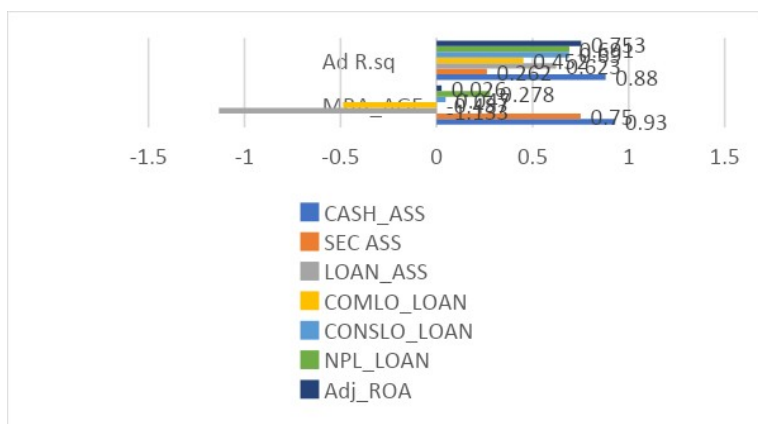
Fig 5. Islamic Banking effect on the large banks using Assets side variables by employing PLS method
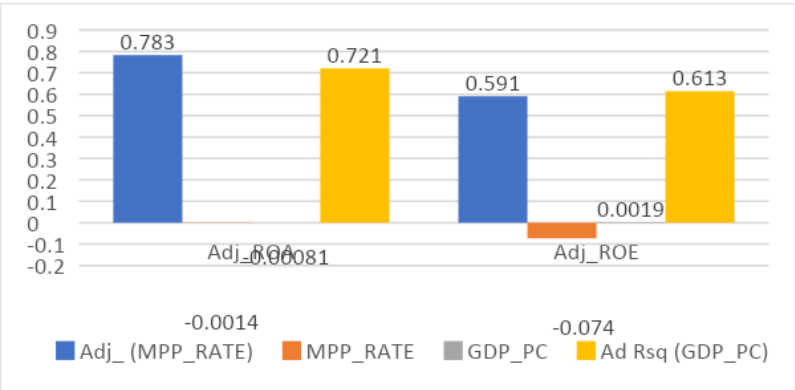
Fig 6. GDP per capita effect, penetration rates of mobile phone on ROE and ROA (large banks)

Finally, from **Fig. 6,** it can be seen that GDP_per_capita positively impacted large banks' adjusted ROE, which was 0.0019, with adjusted R2 being 61.31%. On the other hand, GDP_per_capita had a negative impact on large banks' adjusted ROA, which was -0.00081, including a 77.1% adjusted R2. Islamic Banking application penetration rates have a detrimental impact on Adj_ROE and Adj_ROA in the big banks [21]. As a result, the regression framework demonstrates the total influence of the GDP per capita upon ROE. The ROE and GDP are inextricably linked. More capital would be needed when the economy grows quicker, resulting in greater liquidity and credit inside the finance market [22]. This encourages the Islamic banking methods and its penetration in the Malaysians' economy via inflows through the stock market, resulting in better returns for the financial market [23]. There will be more equity. ROE seems to be more influenced than ROA, which indicates that the financial debt/ investment /leverage is more susceptible to the exterior macroeconomic environment [24]. Furthermore, Islamic FinTech prevalence has a beneficial influence on the small banks' ROE and ROA [25]. Based on the findings, it is possible to infer that banks' performance is influenced by their capacity to harness Modern methodologies, in this case, Islamic FinTech, by increasing Islamic FinTech client base & activating their usage [26].

4. Conclusion

To the best of our knowledge, it is among the few, if not first, studies were undertaken in Malaysia to examine the influence of Islamic Banking on bank performance. The study's findings have far-reaching consequences for future research [27]. To start, most of the existing research on the influence of financial technology innovations on the bank's performance in Malaysia is qualitative [28]. In comparison, our quantitative study comprehensively evaluates the impact of Islamic Banking on the financial performance of banks using variables derived from all the aspects in the financial statements [29]. Our research has some practical consequences. First, the findings indicate that Islamic Banking has a beneficial influence on the bank's performance in Malaysia. It is advised that the commercial banks within Malaysia invest more in Islamic Banking technology to improve their revenue. Second, the influence of Islamic Banking was felt more strongly by small banks than big banks [30]. Shortly, large

banks in Malaysia should explore further investing in Islamic Banking for a more substantial financial capital [16]. Third, the influence of market impacts on a bank's financial performance, such as GDP per capita and Islamic banking app penetration rate, is shown. Our study team has made specific proposals for commercial banks and policymakers, such as further investment or a legislative framework for the future [3]. Regarding future work, the analysis data is one year older than now, broadening the study scope to uncover its long-term consequences. Second, it is highly beneficial to expand the study topic since the influence of Islamic Fintech has no longer [3]

Reference

[1]   S. P. Phung and V. Raju, "Framework assimilation in supply chain management: Exploratory study based on investigation," *Int. J. Supply Chain Manag.*, vol. 8, no. 2, pp. 1090–1094, 2019.

[2]   K. A. Law, A. Bhaumik, H. Yin, and V. Raju, "Effectiveness of mobile phone users based on aging issue: In the context of urban part of china," *Int. J. Control Autom.*, vol. 12, no. 5, pp. 107–113, Nov. 2019.

[3]   V. Raju and S. P. Phung, "Production of methane gas from cow's residue: Biogas as alternative energy in transportation and electricity," *Eurasian J. Anal. Chem.*, vol. 13, no. 6, pp. 121–124, 2018.

[4]   M. Farooq and V. Raju, "Want to Stay the Market Leader in the Era of Transformative Marketing? Keep the Customers Satisfied!," *Glob. J. Flex. Syst. Manag.*, vol. 20, no. 3, pp. 257–266, Sep. 2019, doi: 10.1007/S40171-019-00213-W.

[5]   M. S. Bhuyan and V. Raju, "Strategic management of renewable energy consumption on sustainable development in Bangladesh," *J. Crit. Rev.*, vol. 7, no. 17, pp. 1148–1154, 2020, doi: 10.31838/JCR.07.17.145.

[6]   Z. Yizhou, Z. Simeng, and V. Raj, "A Discussion of the Application of Artificial Intelligence in the Management of Mass Media Censorship in Mainland China," *ACM Int. Conf. Proceeding Ser.*, pp. 79–84, Aug. 2020, doi: 10.1145/3407703.3407719.

[7]   S. N. S. Mohd Adnan and R. Valliappan, "Communicating shared vision and leadership styles towards enhancing performance," *Int. J. Product. Perform. Manag.*, vol. 68, no. 6, pp. 1042–1056, Jul. 2019, doi: 10.1108/IJPPM-05-2018-0183.

[8]   V. Raju, W. Juan, S. Shrestha, A. Kalathinathan, and K. K. Ramachandran, "Role of big data analytics in belt and road initiative (BRI): Multivariate analysis with gaussian distribution of data," *Front. Artif. Intell. Appl.*, vol. 341, pp. 169–177, Oct. 2021, doi: 10.3233/FAIA210245.

[9]   V. Raju and S. P. Phung, "Strategies to enhance supply chain management practices: Identifying the performance orientation," *Int. J. Supply Chain Manag.*, vol. 8, no. 2, pp. 1079–1084, 2019.

[10]   S. P. Phung, V. Raju, and N. A. Latiff, "Meritorious abilities of supply chain management in production environment," *Int. J. Supply Chain Manag.*, vol. 8, no. 2, pp. 1049–1054, 2019.

[11]   S. P. Phung and V. Raju, "Determinants of environmental factors on green supply chain management (GSCM)," *Int. J. Supply Chain Manag.*, vol. 8, no. 2, pp. 1100–1108, 2019.

[12]   S. P. Phung, V. Raju, and R. A. L. Kalimuthu, "Fundamentals of green supply chain management: Organizational measures on implementation," *Int. J. Supply Chain Manag.*, vol. 8, no. 2, pp. 1071–1078, 2019.

[13]   V. Raju and S. P. Phung, "Economic dimensions of blockchain technology: In the context of extention of cryptocurrencies," *Int. J. Psychosoc. Rehabil.*, vol. 24, no. 2, pp. 29–39, Feb. 2020, doi: 10.37200/IJPR/V24I2/PR200307.

[14]   H. Najeeb, V. Raju, and S. Rahman, "Logistics in Yemen: Addressing the weakness of purchasing power to satisfy needs: In context of supply chain design optimization (Case of Yemen)," *Int. J. Supply Chain Manag.*, vol. 8, no. 2, pp. 1200–1204, 2019.

[15]   S. P. Phung, V. Raju, and S. R. Ramzani, "Factors determining managerial role in supply chain management: Study on administrative trait's effects on production," *Int. J. Supply Chain Manag.*, vol. 8, no. 2, pp. 1062–1070, 2019.

[16]   V. Raju, "Implementing Flexible Systems in Doctoral Viva Defense Through Virtual Mechanism," *Glob. J. Flex. Syst. Manag.*, vol. 22, no. 2, pp. 127–139, Jun. 2021, doi: 10.1007/S40171-021-00264-Y.

[17]   S. P. Phung and V. Raju, "Role of decision making in supply chain management in accordance with information and communication technologies," *Int. J. Supply Chain Manag.*, vol. 8, no. 2, pp. 1095–1099, 2019.

[18]   M. Naseer, M. Farooq, W. Younas, and V. Raju, "Antecedents of employee retention in the pharmaceutical industry of Pakistan," *J. Soc. Sci. Res.*, vol. 5, no. 3, pp. 655–664, 2019, doi: 10.32861/JSSR.53.655.664.

[19]   M. Alhamad, M. Nusari, A. Ameen, V. Raju, and A. Bhumic, "Role of judicial specialization on improving the organizational performance within judicial institutions in the United Arab Emirates," *Int. J. Recent Technol. Eng.*, vol. 8, no. 2 Special Issue 10, pp. 328–332, Sep. 2019, doi: 10.35940/IJRTE.B1054.0982S1019.

[20]   A. M. Younus and V. Raju, "Resilient Features of Organizational Culture in Implementation of Smart Contract Technology Blockchain in Iraqi Gas and Oil Companies," *Int. J. Qual. Res.*, vol. 15, no. 2, pp. 435–450, 2021, doi: 10.24874/IJQR15.02-05.

[21]   A. Bhaumik, K. A. Law, Y. Xu, and V. Raju, "Empirical study on employee's psychological capital: Based on guangdong technology enterprises in China," *Int. J. Control Autom.*, vol. 12, no. 5, pp. 88–98, Nov. 2019, doi: 10.37200/ijpr/v24i4/pr201116.

[22]   M. Asvar and V. Raju, "Understanding the causes of time overrun in building construction industry in Cyprus," *J. Crit. Rev.*, vol. 7, no. 17, pp. 1145–1147, 2020, doi: 10.31838/JCR.07.17.144.

[23]   H. Taleb and V. Raju, "Managerial dynamic capabilities and small and medium-sized enterprises' internationalization: Moderating role of environmental dynamism," *Int. J. Adv. Sci. Technol.*, vol. 29, no. 1, pp. 1703–1714, Jan. 2020.

[24]   Z. Simeng, Z. Yizhou, and V. Raj, "Explore the Improvement of the Management of China's International Film Festivals Based on Artificial Intelligence," *ACM Int. Conf. Proceeding Ser.*, pp. 63–67, Aug. 2020, doi: 10.1145/3407703.3407716.

[25]   V. V. R. G. Saigopal and V. Raju, "IoT based Secure Digital Forensic Process according to Process Management," *2020 Int. Conf. Comput. Intell. ICCI 2020*, pp. 229–232, Oct. 2020, doi: 10.1109/ICCI51257.2020.9247710.

[26]   S. S. Raja, V. Raju, and S. S. Raja, "Impact of Entrepreneurship Intention on SocioEconomic Uplift: Moderating Role of Entrepreneurial Infrastructure for Home-Based Start-ups," *Pakistan J. Commer. Soc. Sci.*, vol. 15, no. 2, pp. 426–442, 2021.

[27]   J. E. Adaletey, V. Raju, and S. P. Phung, "Role of stakeholder in revenue mobilization to alleviate poverty in Ghana using E-governance mechanisms," *Int. J. Innov. Technol. Explor. Eng.*, vol. 8, no. 2S, pp. 129–133, 2018.

[28]   M. Kebah, V. Raju, and Z. Osman, "Online purchasing trend in the retail industry in Saudi," *Int. J. Recent Technol. Eng.*, vol. 8, no. 3, pp. 865–868, Sep. 2019, doi: 10.35940/IJRTE.C4053.098319.

[29]   M. Kebah, V. Raju, and Z. Osman, "Growth of online purchase in Saudi Arabia retail industry," *Int. J. Recent Technol. Eng.*, vol. 8, no. 3, pp. 869–872, Sep. 2019, doi: 10.35940/IJRTE.C4054.098319.

[30]   S. U. A. Rana and V. Raju, "Factors influencing glass ceiling focus on women administration in higher education in Malaysia," *Int. J. Eng. Adv. Technol.*, vol. 8, no. 6 Special Issue 3, pp. 461–468, Sep. 2019, doi: 10.35940/IJEAT.F1220.0986S319.

Intelligent Coking Diagnosis Method of Ethylene Cracking Furnace Tube with Data Mining Techniques

Delong Cui [a], Marifel Grace C. Kummer [b], Zhiping Peng [a, c1]
Jiangtao Ou and Chengyuan Fan [d]

[a] *College of Electronic Information Engineering, Guangdong University of Petrochemical Technology, Maoming, China*
[b] *St. Paul University, Philippines*
[c] *Jiangmen Polytechnic, China*
[d] *AI Sensing Technology, Chancheng District, Foshan, China*

Abstract. Aiming at the shortcomings of the current widely used contact and noncontact tube metal temperature measurement technology and the method of diagnosing the degree of coking of the furnace tube, a new tube metal temperature (TMT) measurement method and a method of diagnosing the coking degree of the furnace tube and predicting the coking trend were introduced in this study. Also, referring to the new generation of intelligent temperature-measuring devices developed for measuring TMT, an intelligent temperature-processing algorithm based on machine learning and neural network was proposed. This method not only improved the accuracy of measuring TMT and the accuracy of tube identification but also reduced the technical cost of TMT measurement to some extent.

Keywords Coking diagnosis and prediction, ethylene cracking furnace tube, infrared temperature measurement, intelligent temperature-measuring devices, machine learning, neural network

1. Introduction

Ethylene is the most basic raw material for the petrochemical industry. Ethylene production has been regarded as one of the important indicators of the development level of a country's petrochemical industry. However, while producing ethylene by thermal cracking, carburization and coking are always inevitable in cracking furnace tubes, which greatly affects the production efficiency of ethylene enterprises. The tube metal temperature (TMT) of a cracking furnace tube is one of the most important factors influencing the coking of the tube. Therefore, accurate measurement of the TMT involves diagnosing and predicting the coking degree of the cracking furnace tube. The key problems are to ensure the operation safety of the cracking furnace and improve the production benefit of the furnace, and make the ethylene industry industrial intelligent.

Ethylene cracking furnaces are the key equipment to produce ethylene and cracking furnace tubes as shown in Figure 1. During ethylene production, carburizing and coking in a cracking furnace tube are inevitable. It is inevitable to form coke particles or cokes

---

attached to the inner wall of the furnace tube when a cracking reaction occurs at a high temperature, which is called furnace tube coking, because of the particularity of hydrocarbon cracking raw materials.

Figure 1. External structure of ethylene cracking furnace.

Figure 2 shows a furnace tube coking–induced failure of different levels. If the coking of the furnace tube is not handled in time, it can cause the explosion of the cracking furnace, resulting in heavy casualties and economic losses. For example, on February 23, 2002, a petrochemical enterprise suffered a large amount of raw material leakage due to the coking of the furnace tube, resulting in a cracking furnace explosion, involving eight deaths and one serious injury, and causing serious pollution to the environment.

(a) Moderate coking   (b) Serious coking   (c) Blocking pipe   (d) Cause cipe
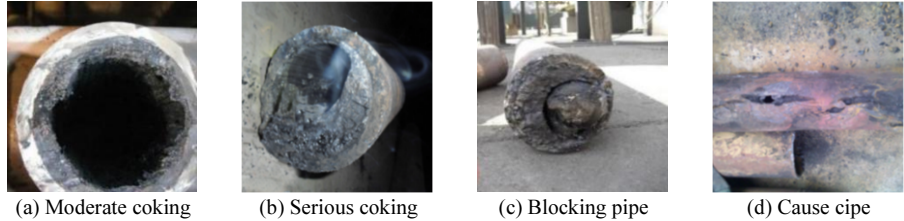
Figure 2. Diagram of furnace tube failure induced by coking to different degrees.

Therefore, in ethylene production, it is necessary to control the process parameters of the cracking process to slow down coking and stop the furnace at the appropriate time to remove the coke on the inner wall of the furnace tube so that the furnace tube meets the production requirements for re-use. According to Jin (2020), controlling the cracking furnace according to the situation and clearing coke at the right time are the key common technical problems to be solved in the ethylene production process. Early coke cleaning can reduce the effective operation period of the cracking furnace (the continuous feeding operation time between two coke cleaning times of the cracking furnace) and reduce the production efficiency. Late clearing of a coke can increase energy consumption, lead to failure, and even cause safety accidents.

This study focused on the problem of coke state perception, diagnosis, real-time transmission of the coking state, and warning information of the cracking furnace based on 5G, and tracing of coke formation for the tubes inside the ethylene cracking furnaces, which is challenging due to the harsh operating environment and the complexity of coke formation during the process.

2. Related Work

2.1. Diagnosing the Coking of the Ethylene Tube

Currently, three methods are used for diagnosing the coking of a tube: (1) construction of a model of the coking mechanism according to the internal mechanism of coking, (2) selection of the input variables related to changes in coking yields and the use of intelligent algorithms, such as machine learning or neural networks, to construct a "black box" model for calculating the coking yield, and (3) use of infrared thermal imaging technology to diagnose the failure of a tube.

In terms of mechanism modeling, Valus et al. proposed a liquid gas, two-phase computational fluid dynamic kinetic model by studying the relationship between petroleum fractionation and gas generation in pyrolysis to predict the lighter petroleum fractions produced, gas generated, and coke formed inside a tube [1]. Solaimany et al. established a new 2D dynamic model by analyzing the pyrolysis of propane and naphtha, applying a second-order turbulence model (k-e) and implementing simplified assumptions to predict the temperatures, velocities, and concentrations of propane and naphtha, which underwent thermal cracking for both laminar and turbulent flows inside the tubes of petrochemical-fired heaters [2]. In a study of a "black box" model, Sun et al. used a genetic algorithm (GA) to optimize a back propagation (BP) neural network model to predict the formation rate of coke in a catalytic cracker. Experiments showed that the GA-BP neural network model produced good predictions [3]. Liu et al. used the AdaBoost algorithm to integrate a multiple-output support vector machine as an intelligent model to correct the parameters and improve the generalization ability and accuracy of the mechanism model [4]. Ren et al. developed a new method of infrared thermal image detection on the basis of theoretical research on high-temperature alloys. They used this method to diagnose the lateral temperature distribution of a furnace outlet and the coking degree of a furnace tube to provide the basis for the safe and stable optimization and equipment maintenance of a cracking furnace [5].

In summary, coking is an extremely complex physicochemical reaction that occurs during pyrolysis. In a mechanism model, some parameters of the construction mechanism model are difficult to obtain accurately in actual production; therefore, the accuracy of this model cannot be guaranteed. The "black box" model has a black box characteristic, thus making the output of the model uninterpretable but making the sample requirements stricter. If the factors changed beyond a certain range during the actual production, the reliability of the "black box" model would be significantly reduced. Infrared thermal imaging technology is not yet widely used because of its high installation and maintenance costs in actual production.

2.2. Coking Situation Sensing of the Ethylene Cracking Furnace Tube

Controlling the ethylene cracking furnaces according to the current situation and timely decoking is the core issue in furnace tube coking diagnosis. Thus, it is necessary to adopt key technologies such as the real-time sensing of the coking state, accurate estimation of the location and thickness of the coking, and discovery of the main cause of coking so as to find a specific way to solve this problem. In the following sections, we described the status and development trends of related research.

Shuming et al. observed that the coking status of ethylene cracking furnace tubes was mainly indirectly determined through regular inspections, sensing of cracking

process parameters, and expert experience [6]. Ethylene production companies generally determine the coking period by periodically checking the cracking process parameters, such as the temperature and pressure drop of the furnace tube inlet and outlet. For example, when the pressure drop of the furnace tube reaches the scorching threshold, the furnace should be shut down for decoking. Shi, in his article "Outlet temperature correlation and prediction of transfer line exchanger in an industrial steam ethylene cracking process" proposed a method to sense the coking of furnace tubes by measuring the temperature of the furnace tube outlet [7]. In Fedorov's study, 10 standards were designed to diagnose the status of the furnace tube in real time, including the main process parameters of the furnace and the ratio of gas flow rate to the tube wall temperature. The ethylene cracking reaction is mainly conducted in the radiant section of the furnace tube, and the temperature of the furnace tube outer wall is an important parameter for the sensing of the furnace tube coking situation [8]. In recent years, several researchers and companies have monitored the temperature of the furnace tube outer wall to diagnose the furnace tube coking situation. The conventional furnace tube outer wall temperature detection technology mainly includes two methods: thermocouple measurement and manual measurement. Ross et al. pointed out one disadvantage of the thermocouple measurement method that the thermocouple probe was easily damaged and prone to temperature drift. Meanwhile, the manual measurement method is characterized by several disadvantages, such as low-temperature measurement efficiency and accuracy, incomplete temperature measurement, and high labor intensity of on-site operators [9]. In recent years, researchers and manufacturers have begun to explore the on-line measurement method of the furnace tube outer wall temperature based on infrared temperature measurement technology. Niu et al. demonstrated an explosion-proof infrared temperature measurement camera embedded in the furnace wall, which enabled multi-point temperature on-line measurement of the furnace tube through infrared image shooting, return, and analysis. However, this method required regular verification and calibration of the infrared thermometer and had an issue of maintaining the camera at room temperature [10]. Peng et al. developed a noncontact infrared temperature-measuring robot for the furnace tube outer wall. A guide rail was installed outside the fire viewing port so that the temperature-measuring robot automatically slid on the guide rail to measure the temperature and achieve multi-point temperature measurement on the furnace tube outer wall [11, 12].

In summary, the temperature of the furnace tube outer wall is an important parameter for diagnosing the furnace tube coking state. The higher the number of points whose temperatures are sensed on the furnace tube outer wall, the more beneficial the technique for diagnosing the furnace tube coking state. Numerous temperature measurement technologies can detect the temperature at multiple points on the furnace tube outer wall. However, it is still difficult to sense the temperature of the outer wall of the entire furnace tube in real time owing to the complexity of the cracking environment (large, high temperature, closed).

3. Research Design

3.1. Architectural Design

The architectural design of the system is shown in Figure 3. As shown in the figure, the architectural design of the proposed system consisted of four layers. The bottom layer

was the data layer, which was used to collect the industrial data when the ethylene cracker was running. Since the modern ethylene industry has widely adopted the DCS system, all the other data in the data layer except TMT could be obtained directly from the DCS and provided services for the upper data mining layer. Above the data layer was the data mining layer. This layer was used according to the data provided by the data layer to diagnose and predict the coking degree of cracking furnace tube. The clustering and classification were used as for data mining to determine the TMT of each furnace tube and measure the temperature based on the collected data. The system also used CNN to distinguish different tubes of observation holes. The algorithms were achieved using the Python language.
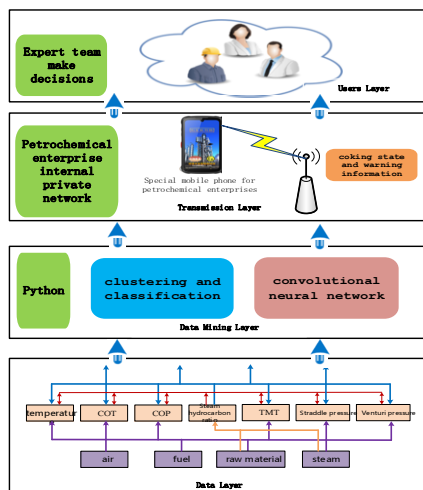
Figure 3. Architectural design.

Above the data mining layer was the transmission layer. Due to the requirements of industrial information security, the industrial data generated by the ethylene cracking furnace could not be transmitted through the public network. Therefore, the ethylene enterprises set up an internal private network. The coking state and warning information of the cracking furnace tube obtained by the data mining layer went through the internal private network sent to the mobile phone of the person who had permission to view the running status of the ethylene cracking furnace. The ability to be brought into the ethylene production site was also required to meet the production safety requirements of ethylene enterprises. The top layer was the user layer composed of the expert team of the ethylene enterprise. The expert team made decisions on the running state of the ethylene cracking furnace according to the received coking state and warning information. The coking state and warning information included moderate coking, serious coking, blocking pipe, and cause pipe. If the cracking tube was in moderate coking condition, the ethylene cracking furnace could operate normally. If the cracking furnace tube was in serious coking condition, the expert team immediately went to the ethylene production site to confirm the running status of the cracking furnace. If the site status was consistent with the status sent by the intelligent coking diagnosis system, the field operator manually stopped the operation of the cracking furnace. This intelligent coking diagnosis system was designed to avoid blocking pipe and cause pipe due to negligence during manual inspection. Therefore, if the system sent out the information that the cracking

furnace pipe was blocking pipe and cause pipe, the expert team immediately ordered the field operator to stop the operation of the cracking furnace.

3.2. Software

The system consisted of six modules:

- Temperature data maintenance. Temperature data maintenance included two functions: latest temperature data and temperature data query.

- Pressure data maintenance. Pressure data maintenance included Venturi data management and cross-section data query.

- Furnace tube data comparison. The furnace tube temperature comparison included two functions: temperature data comparison and pressure data comparison.

- Furnace tube coking diagnosis. After selecting the time and furnace number, Start Analysis was clicked. The user hovered the mouse over a bar chart to view the coking trend of a tube, clicked on a bar chart to lock the tube coking trend chart represented by the bar chart, and clicked the Back button in the upper-right corner to return to the original bar chart, as shown in Figure 4.
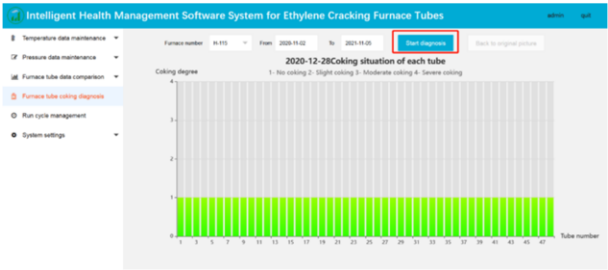
Figure 4. Tube coking trend analysis.

- Operating cycle management. Operating cycle management included the addition, modification, deletion, query, and sorting of the operating cycle of furnace tubes.

- System settings. System settings included user information management and furnace tube warning temperature setting.

3.3. Hardware

The device combined the advanced technology of photoelectric, computer, and wireless communication, and it could be applied to the automatic positioning, external surface measurement, and temperature screening of the tube of the ethylene cracking furnace. The device needed corresponding upper computer software for the intelligent coking diagnosis of the inner wall of the furnace tube, as shown in Figure 5.

The accurate temperature of the outer wall of each tube in the cracking furnace during preprocessing, analysis, and evaluation was obtained through temperature measurement position and angle of the adaptive optimization, cracking furnace jitter reduction, automatic determination of furnace pipe weight, and abnormal measurement data processing, using an intelligent algorithm according to the furnace tube identification rules. The final temperature data were transmitted to the intelligent coking

diagnosis software system of the cracking furnace tube in a wireless manner. The technology parameters of the thermometer are shown in Table 1.
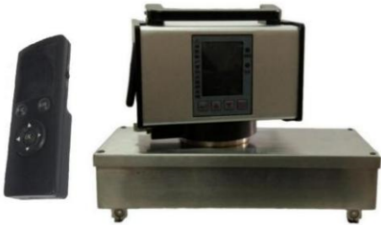
Figure 5. Hardware of intelligent coking diagnosis methods of ethylene cracking furnace.

Table 1. Technology parameters of intelligent thermometer

Technical specification	Parameter
Size	$165 \times 110 \times 135$ mm^3
Shell material	304 stainless steel
Working voltage	24 VDC
Working frequency	433 MHz
Running temperature	−5℃ to +80℃
Operating relative humidity	0%–99%
Temperature measurement range	0℃ to +1400℃
Accuracy of temperature measurement error	±0.5℃
Temperature-measuring distance	0.06–5 m
Temperature-measuring distance between thermometer and observation hole	<1.5 m
Single view of the fire hole temperature measurement points	600–900
Measuring angle range	0–180 degree
Identification rate of fire hole and furnace tube	100%
Measuring time for each cracking furnace	<9 min

The actual application scenario of this system in an ethylene enterprise is shown in Figure 6.

Figure 6. Application of intelligent temperature-measuring device and software in petrochemical enterprises.

3.4. Key technical details

Due to space limitations, this section described two core technologies adopted by the system.

3.4.1 Calculation method for the outer surface temperature of the furnace tube in the cracking furnace based on data mining technology

First, we assumed the cracking furnace tube temperature data set as $D_T = \{a_1, a_2, \cdots, a_n\}$, and then the characteristics of temperature data points D_T were analyzed. The parameters in the algorithm (Eps, MinPts) were set, and the distance between data points in the dataset was calculated.

Second, for the data points in the temperature data set, the following steps were used to find out all the core objects:

Step 1: We found the Eps-neighborhood subsample set $Eps(a_i)$ of data point a_i by the selected distance measurement method.

Step 2: If the number of data points in the Eps-neighborhood subsample set of data point a_i met the core object discrimination equation, we added data point a_i to the core object sample set Ω.

Third, in the core object set Ω, an unclassified core object *w* was randomly selected to find the sequence composed of all data points with reachable density. Then, all data points $C_T = \{b_1, b_2, \cdots, b_n\}$ in the Eps-neighborhood of the sequence were obtained using the Eps-neighborhood equation, which was the cluster of furnace tube temperature data.

Finally, according to the obtained cluster of furnace tube temperature data C_T, the final external surface temperature of the furnace tube in the current cracking furnace was calculated using equation 1. The description of the algorithm for calculating the temperature of the outer surface of the furnace tube in a cracking furnace was as follows:

$$TMT = \frac{sum(b_1, b_2, \cdots, b_n)}{length(C_T)} \tag{1}$$

Algorithm 1: Calculation of TMT of the furnace tube based on data mining

---

Input: $D_T = \{a_1, a_2, \cdots, a_m\}$: Cracking furnace tube temperature data set

Output: TMT external surface temperature of the furnace tube in the cracking furnace

1. Initialize the collection of core objects $\Omega = \varnothing$

2. **for** $i \leq m$ **do**

    Finding the *Eps*-neighborhood subsample set $Eps(a_i)$ of data points a_i

3.   **if** $|Eps(a_i)| \geq MinPts$ **then**

4. $\Omega = \Omega \cup \{a_i\}$

5.   **end if**

6.   **end for**

7.   In the core object collection Ω, randomly select an unclassified core object ω

8.   Find the ω for all data points with reachable density in the sequence S_T

9.   Obtain all data point sets C_T of set *Eps*-neighborhood in set S_T

10.   Calculate the external surface temperature of the cracking furnace tube using equation (1).

3.4.2 Use of CNN to distinguish different tubes of observation holes

CNN is extensive use in term of classification and clustering[12-15]. The composition of the data set used for CNN training and testing is shown in Figure 7. Figure 7(a) shows the two-dimensional distance characteristic diagram of part of normal furnace tubes, while Figure 7(b) shows the two-dimensional distance characteristic diagram of part of overlapping furnace tubes. The characteristic diagram is 32×32 gray scale diagram. The extraction method of the two-dimensional distance characteristic graph of furnace tube was as follows:

First, the distance data of all furnace tubes were extracted from the one-dimensional distance data collected by the intelligent thermometer, and the distance data of each furnace tube constituted a set A_i. The set of distance data of the Kth furnace tube A^k was expressed using equation (2), and a_n stands for the distance value of the Nth furnace tube in the set.

$$A_k = \{a_1, a_2, \cdots, a_n\} \tag{2}$$

Then, using equation (3), the data with low correlation with the distance characteristics of the Kth furnace tube were removed to obtain the set A_k'.

$$a_i' = a_i - min\{a_1, a_2, \cdots, a_n\} + b, \quad i = 1, 2, \cdots, n \tag{3}$$

where b is a constant 10.

Then, the distance value D, which was used to represent the furnace tube boundary, was added at both ends of the set A_k' to obtain the final distance feature set $C_k = \{d, a_1', a_2', \cdots, a_n', d\}$ of the Kth furnace tube, where d is a constant 300.

Finally, the distance feature set C_k was transformed into a two-dimensional bar graph and saved as a grayscale graph with a size of 32×32 so that the two-dimensional distance feature graph of the Kth furnace tube was obtained.
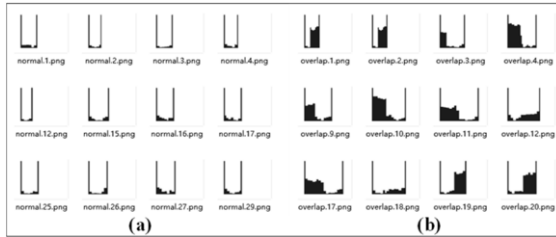
Figure 7. Two-dimensional distance characteristic map of the furnace tube.

4. Conclusions

This study introduced the intelligent coking diagnosis of the ethylene cracking furnace tube for ethylene enterprises, which improved the coke formation diagnosis abilities from qualitative judgment to fine quantitative inference and root cause traceability. It provided a scientific basis for condition-based operation optimization and appropriate and timely decoking, and pushed forward the intelligentization, greenization, and securitization of ethylene production.

Acknowledgments

References

[1] Valus M G, Fontoura D V R, Serfaty R, et al. Computational fluid dynamic model for the estimation of coke formation and gas generation inside petrochemical furnace pipes with the use of a kinetic net [J]. Canadian Journal of Chemical Engineering, 2017, 95(12): 2286-2292.

[2] Solaimany Nazar A R, Banisharifdehkordi F, Ahmadzadeh S. Mathematical Modeling of Coke Formation and Deposition due to Thermal Cracking of Petroleum Fluids [J]. Chemical Engineering and Technology, 2016, 39(2): 311-321.

[3] Sun X, Wu Y, Pei H, et al. Prediction of Coke Yield of FCC Unit Using Different Artificial Neural Network Models [J]. China Petroleum Processing and Petrochemical Technology, 2016, 18(3): 102-109.

[4] Liu L, Li Y, Fang L, et al. Soft Measurement of Ethylene Cracking Coking Amount Based on Adaboost Hybrid Model [J]. Automation and Instrumentation, 2015, (6): 50-53.

[5] Ren S, Zhang Z. Research on Infrared Thermal Image Detection and Evaluation Technology of Ethylene Cracking Furnace Tube [J]. Modern Industrial Economy and Informationization, 2015, 5(6): 31-32.

[6] Wang Shuming. Measures to realize long period and high efficiency operation of cracking furnace [J]. Refining & Chem Industry, 2018, 29(01): 30-32.

[7] Shi H Y, Peng B, Jiang X Y, Su C L, Cao J T, Li P. A hybrid control approach for the cracking outlet temperature system of ethylene cracking furnace [J]. Soft Computing, 2020, 24(16): 12375-12390.

[8] Fedorov S N, Krasnov A N, Prakhova M Y. Algorithm for diagnostics of technical condition of the tube furnace coils [C]. 2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon), Vladivostok, Russia, 2020: 1-6.

[9] Ross-Pinnock D, Maropoulos P G. Review of industrial temperature measurement technologies and research priorities for the thermal characterisation of the factories of the future [J]. Journal of Engineering Manufacture, 2016, 230(5): 793-806.

[10] Niu Guanbo, Yu Shiheng.Application of infrared on-line temperature field detection system in cracking furnace of ethylene plant [J]. Automation of Petrochemical Industry, 2020, 56(4): 72-74.

[11] Peng Z P, He J G, Tan Y, Cui D L, Li Q R, Qiu J B. Study of dual-phase drive synchronization method and temperature measurement algorithm for measuring external surface temperatures of ethylene cracking furnace tubes [J]. Applied Petrochemical Research, 2018, 8(3): 163-172.

[12] Zhao J F, Peng Z P, Cui D L, Li Q R, He J G, Qiu J B. A method for measuring tube metal temperature of ethylene cracking furnace tubes based on machine learning and neural network [J]. IEEE Access, 2019, 7: 158643-158654.

[13] Zou Z, Ge J, et al. Encrypted Traffic Classification with a Convolutional Long Short_Term Memory Neural Network[C]. IEEE 20nd International Conference on High Performance Computing and Communications, 2018: 329-334.

[14] Rezaei S, Kroencks B, Liu X, et al. Large-Scale Mobile App Identification Using Deep Learning[J]. IEEE Access, 2019, 8(1): 348-362.

[15] Peng L, Chen Z, Yang L T, et al. An impronved Stacked Auto-Encoder for Network Traffic Flow Classification[J]. IEEE Network, 2018, 32(6): 22-27.

Construction and Analysis of Enterprise Innovation Capability Evaluation Model – A Case Study of 30 Listed Companies in Gansu Province

Jinghan LI[1]
Northwest Minzu University, Lanzhou, Gansu, 730030, China

Abstract. Listed companies are the backbone of the regional economic growth. The enterprise innovation capability is the ability of the enterprises to integrate the internal and external resources through multi-dimensional innovation activities to improve the enterprise performance and obtain the economic benefits in a short period. This paper constructs the evaluation index system and evaluation model of enterprise innovation ability from three perspectives: technological innovation ability, institutional innovation ability and management innovation ability, and uses the improved AHP method to determine the weight of each index. Based on the data of 30 listed companies in Gansu Province from 2016 to 2020, this paper measures their innovation efforts and suggests the ways to improve their innovation ability.

Keywords. Listed companies in Gansu Province, Evaluation of innovation ability, Improved analytic hierarchy process

1. Introduction

For a country or a region to achieve leapfrog development, the key lies in using technological innovation to achieve the economic growth and sustainable development. Marx and Schumpeter emphasized innovation at the center of the economic growth theory in 19th and 20th century respectively[1]. Chris Freeman (1971), a British economist, believed that innovation refers to the introduction of technology, design, production, finance, market, management and many other steps involved in a new product or process for the first time[2]. Schumpter (1912) regarded innovation as the implementation of new combinations of factors and conditions of production[3]. Mansfield (1971), in his "technology extension theory", believed that innovation as such is an invention or the first application of technological changes in the existing products in furtherance of business activities[4].

Mensch, a German-American economist, believed that innovation refers to the application of technological progress in economic development[5]. The diffusion of

---

[1] Corresponding Author: Jinghan LI, Northwest Minzu University, Lanzhou, Gansu, 730030, China; Email: Xbmulzjh@126.com

technological innovation and the application of new products and technologies boost the national economy as a whole. When the technology deadlock occurs, the economy may stagger or even decline.

Clarifying the dominant position of enterprises in scientific and technological innovation is the fundamental way to improve the independent innovation ability of the enterprises. Rammer's (2011) empirical analysis of the German manufacturing industry proved that a large number of enterprises without technological innovation have lower economic income than those with technological innovation[6]. The empirical analysis of large American enterprises (Cohen, 1987)[7], Spanish enterprises (Galende and Suarez, 1999)[8] and European enterprises (Arundel, 2008)[9] also corroborated that the technological innovation ability is not the only source for enterprises to obtain competitive advantages. Enterprises having no R&D even exhibit higher productivity and economic benefits than the R&D enterprises (Kimer, 2009)[10], which poses an important challenge to the traditional innovation theory that "enterprises without R&D or low technological innovation rate mean stagnation or even recession". At the same time, the priority given by the economists to the technology innovation strategy points out a very important fact that although the environment or system is similar, but because of the niche business belonging to different areas, the innovation of the enterprise strategic activities in multiple dimensions show obvious heterogeneity indicating that the enterprise innovation ability should be diversified.

Since 1990s, researchers have further supplemented the connotation of enterprise innovation, making it no longer limited to technological innovation. Chang Huize (1994) believed that enterprise institutional innovation and technological innovation are interrelated and mutually promoting[11]. Institutional innovation in a narrow sense is organizational innovation, mainly referring to the enterprise property rights system. Japanese scholar Ikujiro Nonaka et al. (2006), in their book "Enterprises That Create Knowledge: The Driving Force for Continuous Innovation of Japanese and American enterprises" emphasized that the Japanese and United States enterprises are involved in the dynamics of continuous innovation and proposed a theory of enterprise sustainable innovation, pointing out that the fundamental task of these companies is continuous introduction of enterprise innovation, and management of institutional projects[12]. They further pointed that it comprises a variety of innovative enterprise innovation ability and project cluster dynamic nonlinear complex process of system integration. In the investigation of successful enterprises at home and abroad, Wang Dazhou et al. (2001), observed that the institutional arrangement provides preconditions for technological innovation and supporting conditions for institutional innovation thereby, contributing to the growth of the enterprises[13]. Duan Yunlong (2009) concluded that the institutional category that influences technological innovation includes not only the macro institutional environment, but also the meso institutional arrangements between the enterprises and the micro institutional arrangements within the enterprise[14]. For example, the R&D incentive system established within the enterprise belongs to the micro institutional arrangement. According to the characteristics of the enterprises' technological innovation ability, Fu Jiaji (1998) constructed the index system of enterprises' technological innovation ability in R&D, innovation resource investment, management innovation, marketing, innovation tendency and manufacturing[15].

To sum up, the technological innovation plays a decisive role in economic growth however, the important role of institution in technological innovation and economic growth is rather ignored. The enterprise system innovation provides a guarantee for smooth implementation of technology innovation, system innovation and technological

innovation by investing more in R&D and promotes the growth of the economy. It gradually develops into a complex of various capabilities with technological innovation capability as the core and other innovation capabilities as the auxiliary development measures. Although the environment or the system of enterprises is similar, the innovation capability should be diversified especially, for the listed companies with large gaps in industrial attributes there is significant heterogeneity in the innovation capabilities. Based on the aforesaid research, this paper defines the connotation of the enterprise's innovation capability as follows: In a foreseeable period, the enterprise realizes the integration of the internal and external resources through multi-dimensional innovation activities such as technological innovation, institutional innovation and management innovation, and ultimately improves the enterprise's performance and gets economic benefits.

In the technological and economic globalization environment, a new round of scientific and technological revolution is booming, and innovation is becoming more and more open. The advanced theoretical basis represented by collaborative manufacturing has become the pre paradigm. The realization of the innovation mode of openness, cooperation and sharing has proved to be an important way to effectively improve the efficiency of innovation. Of late, the research trend is to explore how to integrate enterprises, governments, and knowledge exploring institutions (such as universities and research organizations) to establish a long-span innovation organization model based on the perspective of knowledge appreciation and the goal orientation of realizing major scientific and technological innovation. As suggested by Chesbrough et al. (2011), companies should find a way to utilize the distributed pools of knowledge possessed by customers, suppliers, universities, national labs, consortia, consultants and even their own competitors[16]. Chen Jin et al. (2012) established a theoretical framework of collaborative innovation from two dimensions, namely integration dimension and interaction intensity, and proved that the collaborative innovation is mainly manifested in the process of industry-university research cooperation[17].

Rexhepi et al. (2019) explored the initial model of knowledge production - the Triple Helix, representing an innovation system model through the interactions of three 'helices' in knowledge production: universities-industry-governments[18]. Xie Ruoqing et al. (2020) evaluated the innovation capability of Chinese industrial listed companies; they introduced the collaborative innovation capability into the evaluation system as a primary index[19]. Zhang Zhi He et al. (2016) established the innovation ability index system of listed companies in Shan Xi Province and concluded that the enterprises should closely link technological innovation ability in formulation of technological strategy, collaborative innovation and R&D activities[20]. Although the above findings noticed the importance of collaborative innovation suffers from the main drawback that these studies do not consider the specific indicators that can fully reflect the process of enterprise industry-university research cooperation into the evaluation system. Therefore, based on the collaborative innovation theory and open innovation model, this paper introduces some indicators which missed in the previous evaluation index system of innovation ability, such as the number of industry-university research cooperation platforms, the number of awards for scientific and technological achievements at the provincial, ministerial level or above, the number of innovative R&D projects invested by raising funds, etc.

2. Construction of Enterprise Innovation Capability Evaluation Model

The main research methods to evaluate the enterprise innovation ability focus on the analytic hierarchy process (AHP) and multistage fuzzy comprehensive evaluation method, grey correlation method, principal component analysis and BP neural network model, data envelopment analysis, factor analysis, etc. Li qun, LingKang (2004) used multilevel fuzzy comprehensive evaluation from the six elements level and constructed enterprise innovation ability evaluation index[21]. Zhao Wenyan and Zeng Yueming (2011) used an analytic hierarchy process (AHP) to decompose the index system layer by layer and constructed an evaluation system of enterprise innovation capability[22]. Wang Mengqiu (2012) used analytic hierarchy process to construct an evaluation index system of innovation capability of innovation-oriented enterprises from four aspects: innovation input, innovation realization, innovation output capacity and innovation environment[23].

The AHP can be used to subdivide the main factors into higher index levels according to the process capability model, and then analyze the assigned weight of indicators at each level, which was more intuitive and convenient in processing. Figure 1 depicts the results of the enterprise innovation capability evaluation model construction. Under the technological innovation ability, there are three secondary indexes: technological innovation investment ability, technological innovation transformation ability and technological innovation marketing ability, which fully reflect that the technological innovation is an economic concept rather than a technological concept as a mechanism of continuous operation. The system innovation ability consists of two secondary indexes – the property right system innovation ability and the incentive system innovation ability. The property rights system is the core of the enterprise system which determines the organization form of enterprise property while the operational mechanism is seen as the key to the institutional innovation in state-owned assets management, and the incentive system improves the mechanism of the success rate of technology innovation. Under the management innovation ability, there are two secondary indexes: the enterprise innovation consciousness intensity and the operation innovation management ability, which reflects the consciousness and the ability of the enterprises to integrate the existing resources.
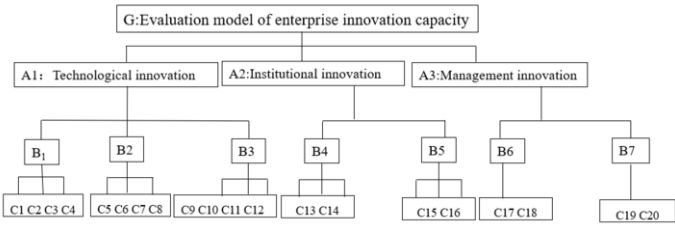
Figure. 1 Evaluation model of enterprise innovation ability

3. An Empirical Study on the Evaluation of Innovation Ability of Listed Companies in Gansu Province

3.1 Construction of innovation capability index system of an enterprise

The evaluation index system of the enterprise innovation capability is divided into three index levels. Under the target level, the innovation capability is decomposed into three basic elements according to the dimension of the enterprise innovation activities, namely, technological innovation capability, institutional innovation capability and management innovation capability, which constitute the first-level index level. There are seven second-level indicators under the first-level indicator layer namely, technological innovation investment ability, technological innovation transformation ability, technological innovation marketing ability, property rights system innovation ability, incentive system innovation ability, enterprise innovation consciousness intensity, and operation innovation management ability. Twenty three-level indicators are set under the second-level indicator layer. Considering the difficulty of data acquisition and the strong willingness of enterprises to publicly disclose information, 20 three-level indicators are finally selected: per capita R&D expenditure, proportion of bachelor degree or above, proportion of R&D expenditure in main business income, proportion of the number of researchers and so on.

Collect index scores at all levels as the core, design the questionnaire, and solicit scoring opinions from six experts engaged in innovative enterprise research in the form of electronic questionnaire, including professors in major universities, general partners of private equity funds with innovative enterprises as investment targets, heads of scientific and innovative financial services companies, etc. Table 1~7 depict the construction of the innovation capability index system of an enterprise used in the study.

Table 1 Enterprise innovation capability index system: Technological innovation investment ability

First Level	Second Level	Third Level	Attribute	Meaning
A1 Technological Innovation Ability	B1 Technological Innovation Investment Ability	C1:Per capita R&D expenditure	Positive index	C1=R&D expenses / total number of active employees
		C2:Proportion of bachelor degree or above	Positive index	C2=Number of employees with bachelor degree or above / total number of on-the-job employees
		C3:Ratio of R&D expense to main business income	Positive index	C3=R&D expenses / main business income
		C4:Ratio of the number of Researchers	Positive index	C4=Number of researchers / total number of active employees

Table 2 Enterprise innovation capability index system: Technological innovation transformation ability

First Level	Second Level	Third Level	Attribute	Meaning
A1 Technological Innovation Ability	B2 Technological Innovation Transformation Ability	C5:Weighted return on equity after deducting non-operating losses	Positive index	C5=(total profit - non operating income + non operating expenditure) * (1 - income tax rate)
		C6:Growth rate of main business income	Positive index	C6=(main business income of the current period / main business income of the previous period) – 1
		C7:Number of awards for scientific and technological achievements at provincial and ministerial level and above	Positive index	C7=Number of scientific and technological achievements of enterprises at provincial and ministerial levels and above
		C8:Per capita patent holdings of Employees	Positive index	C8=Number of valid patents / total number of employees

Table 3 Enterprise innovation capability index system: Technological innovation and marketing ability

First Level	Second Level	Third Level	Attribute	Meaning
A1 Technological Innovation Ability	B3 Technological Innovation and Marketing Ability	C9:Proportion of sales personnel	Positive index	C9=Number of salespeople / total number of active employees
		C10:Per capita sales expense Investment	Positive index	C10=Sales expenses / total number of employees
		C11:Number of investment institutions settled	Positive index	C11=Number of investment institutions among the top ten shareholders
		C12:Number of industry university research cooperation platforms	Positive index	C12=Number of platforms jointly built by enterprises, universities and scientific research institutes

Table 4 Enterprise innovation capability index system: Innovation ability of property right system

First Level	Second Level	Third Level	Attribute	Meaning
A2 Institutional Innovation Ability	B4 Innovation Ability of Property Right System	C13:Shareholding ratio of state-owned legal person	Positive index	C13= State owned shares / total shares
		C14:Proportion of tradable shares	Positive index	C14=Number of outstanding shares / total shares

Table 5 Enterprise innovation capability index system: Incentive system innovation ability

First Level	Second Level	Third Level	Attribute	Meaning
A2 Institutional Innovation Ability	B5 Incentive System Innovation Ability	C15: Proportion of total issued incentives to total share capital	Positive index	C15= Total number of shares / total share capital corresponding to equity incentive plan
		C16: Total annual salary of directors and supervisors	Positive index	C16= Total annual salary of directors, supervisors and other senior managers

Table 6 Enterprise innovation capability index system: Enterprise innovation consciousness intensity

First Level	Second Level	Third Level	Attribute	Meaning
A3 Management Innovation Ability	B6 Enterprise Innovation Consciousness Intensity	C17:Number of innovative R&D projects invested by raising funds	Positive index	C17=The number of projects that raise funds to invest in innovative research and development
		C18:Patent efficiency	Positive index	C18=1- Number of invalid patents/ total number of patents

Table 7 Enterprise innovation capability index system: Operation innovation management capability

First Level	Second Level	Third Level	Attribute	Meaning
A3 Management Innovation Ability	B7 Operation Innovation management capability	C19:Inventory turnover	Positive index	C19=Operating income/average inventory balance
		C20:Management expenditure Efficiency	Positive index	C20=Main business income / management expenses

3.2 Decision making process of analytic hierarchy process

Analytic hierarchy process (AHP)is a systematic analysis method of multi-criteria decision-making proposed by T.L. satty[24], an American operations research scientist and professor at the University of Pittsburgh in the early 1970s. Using AHP method, it is easy to divide many factors into levels according to the process capability model and evaluate and analyze them layer by layer, which is intuitive and simple. However, as the research conclusion summarized by Xu Liping(2015), subjective factors have a great impact on the evaluation of objectives[25].This paper adopts the three scale matrix method (Luo & Wang, 1993;Sang & Lin & Ji,2002; Cao & Wang, 2018) which educes the designer's subjective judgment in the decision-making process [26-28].

3.2.1 Establish hierarchical structure model

The hierarchical structure of some elements is divided into a group of elements dominated by the hierarchical structure, such as the hierarchical structure of some elements. At the same time, these elements are divided into a group of elements dominated by the hierarchical structure according to the hierarchical structure of the elements. For example, the hierarchical structure of these elements is shown in the Figure 2.

Figure. 2 Structure of ladder level

3.2.2 Comparison and judgment matrix

The judgment matrix is the information basis of AHP method. The value of the judgment matrix element reflects the relative importance of each element in the problem. The traditional judgment and evaluation method adopts the scale of 1 ~ 9, and the meaning of the scale is shown in Table 8.

Table 8 Relative importance judge demarcate of AHP

Scale	Define
1	The two indicators are of equal importance
3	The former is slightly more important than the latter
5	Compared with the two indicators, the former is obviously more important than the latter
7	The former is strongly more important than the latter
9	Compared with the two indicators, the former is more important than the latter
2, 4, 6, 8	The intermediate value of the two adjacent judgments above
The bottom	If the comparison of index I with j makes judgment aij, then the comparison of index j with I makes judgment aji=1/aij

The key link in determining the index weight by AHP method is to establish the judgment matrix at all levels. However, in practical application, it may be difficult for experts to adapt to and be familiar with the 1 ~ 9 scale method when giving the judgment matrix. There is a simplified method. The center of simplification is how to make experts give the judgment matrix more easilyand intuitively. The simplified contents are as follows.

(1) Establish comparison matrix A

A three scale method was used to compare the importance and establish the comparison judgment matrix A_{ij}

Table 9 Value setting

Value setting of a_{ij}	Meaning
0	Indicates that the i-th element is "unimportant" compared with the j-th element
1	Indicates that the i-th element is "equally important" compared with the j-th element
2	Indicates that the i-th element is "important" compared with the j-th element

(2)Then calculate the sum of the row elements of the three scale comparison matrix:

$$r_i = \sum_{j=1}^{n} d_{ij} ; i = 1,2,3,...,n$$

Find out the maximum value r_{max} and the minimum value r_{min} min from r_i, then compare the two elements corresponding to r_{max} and r_{min}, and give the so-called base point comparison scale b_m; finally, the direct comparison matrix is transformed into an indirect judgment matrix through the following transformation formula:

$$a_{ij} = \begin{cases} \dfrac{r_i - r_j}{r_{max} - r_{min}}(B_m - 1) + 1, r_i \geqslant r_j \\[4mm] 1 / \left[\dfrac{r_j - r_i}{r_{max} - r_{min}}(B_m - 1) + 1 \right], r_i < r_j \end{cases}$$

This judgment matrix has the following properties:

① $\begin{cases} 1/b_m \leqslant a_{ij} \leqslant 1; & a_{ij} < 1 \\ 1 \leqslant aij \leqslant b_m; & aij \geqslant 1 \end{cases}$

Tthe numerical range of a_{ij} is the scale of $1 \sim b_m$.

② $a_{ij} = 1 / a_{ji}$

The reciprocal property of the symmetric elements of the matrix is still maintained.

③ When $b_m = 9$, it is the scale of $1 \sim 9$.

3.2.3 Calculate the relative weight of elements under a single index

This step is to solve the problem of calculating the ranking weight of n elements $A_1, A_2,..., A_n$ under the index C_k, and carry out the consistency test.

For $A_1, A_2,..., A_n$, the judgment matrix A is obtained by pairwise comparison, and the eigenvalue of the solution matrix $AW = \lambda_{max} W$, the obtained W is normalized as the ranking weight of elements $A_1, A_2,..., A_n$ under the index c_k, this method is

called the eigenvalue method of ranking weight vector calculation. λ_{max} exists and is unique, W can be composed of positive components. W is unique except for a constant multiple.To check the consistency of the judgment matrix, the consistency index shall be calculated according to formula: $H = (\lambda_{max} - n) / (n\text{-}1)$, λ_{max} is the maximum eigenvalue of the judgment matrix.

When $H = 0, \lambda_{max} = n$, the symmetric matrix has complete consistency; When $H > 0$, the value of H is often compared with the average random consistency index L. when the random consistency ratio $M = H / L < 0.10$, it is considered that the matrix has satisfactory consistency; Otherwise, the matrix needs to be adjusted until it is satisfactory.

For matrices of order $1 \sim 9$, the L value is shown in Table 10.

Table 10 The average random coherence weight L

Order number	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54	1.56	1.58	1.59

3.2.4 Calculate the combination weight of each layer element

The importance weights of all factors in the previous level can be calculated from the results of the single ranking of the previous level, that is, the total ranking of the levels.

Suppose that the combined weight vector of the elements of layer $k-1$ relative to the total target is $\alpha^{k-1}, \alpha^{k-1} = (\alpha_1^{k-1}\alpha_2^{k-1}...\alpha_m^{k-1})^T$. The k th layer takes the j th element of the $k-1$ layer as the criterion, and the ordering weight vector of the elements is $B_j^{k}, B_j^{k} = \left(b_{1\,j}^{k}b_{2\,j}^{k}...b_{n\,j}^{k}\right)^T$, the combined weight vector of the elements of layer k relative to the total target is given by the following formula:

$$\alpha^k = B^k \alpha^{k-1}$$

If the calculation results of layer k-1 are known as H_{k-1}, L_{k-1} and M_{k-1}, the corresponding indexes of layer k :

$$H_k = \left(H_k^{1}H_k^{2}...H_k^{m}\right)\alpha^{k-1}$$

$$L_K = \left(L_k^{1}L_k^{2}...L_k^{m}\right)\alpha^{k-1}$$

$$M_k = \left(M_{k-1} + H_k / L_k\right)$$

H_k^{i} and L_k^{i} are the consistency index and average random consistency index of the judgment matrix under the i th index of k layer, respectively. When $M_k < 0.10$, it is considered that the hierarchical level has satisfactory consistency on the whole k level.

Taking the judgment matrix constructed by A_2 as an example, its 1-9 scale matrix and three scale comparison matrix are respectively expressed as follows:

$$A_{ij} = \begin{pmatrix} 1 & 3 & 5 & 3 \\ 1/3 & 1 & 5 & 3 \\ 1/5 & 1/5 & 1 & 5 \\ 1/3 & 1/3 & 1/5 & 1 \end{pmatrix}$$

$$i = 5,6,7,8, j = 5,6,7,8$$

$\lambda_{max} = 4.7653$, $K = 0.2551$, $M = 0.2834 > 0.1$ indicates poor consistency

$$B_{ij} = \begin{pmatrix} 1 & 2 & 2 & 2 \\ 0 & 1 & 2 & 2 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 7 \\ 5 \\ 3 \\ 1 \end{pmatrix} = r_i;$$

$$i = 5,6,7,8, j = 5,6,7,8$$

$$r_{max} = 7, r_{min} = 1, b_m = 9$$

Indirect judgment matrix:

$$C_{ij} = \begin{pmatrix} 1 & 11/3 & 19/3 & 9 \\ 3/11 & 1 & 11/3 & 19/3 \\ 3/19 & 3/11 & 1 & 11/3 \\ 1/9 & 3/19 & 3/11 & 1 \end{pmatrix} = \begin{pmatrix} 0.5447 \\ 0.0956 \\ 0.1799 \\ 0.1799 \end{pmatrix}$$

$$i = 5,6,7,8, j = 5,6,7,8$$

$\lambda_{max} = 4.1861$, $K = 0.0620$, $M = 0.0689 < 0.10$,meets   consistency requirements.

Its weight coefficient vector can be expressed as $(0.5477, 0.0956, 0.1799, 0.1799)^T$ .Similarly, the factor indicators of the second and third levels can be calculated.

Based on the comparison matrix given by expert, establish judgment matrix, anti-symmetric transfer matrix, optimal transfer matrix and quasi optimal consistency matrix respectively. The specific assignment results are shown in Figure 3.

3.3 The Result and Analysis of Index Weighting Based on Improved AHP Method
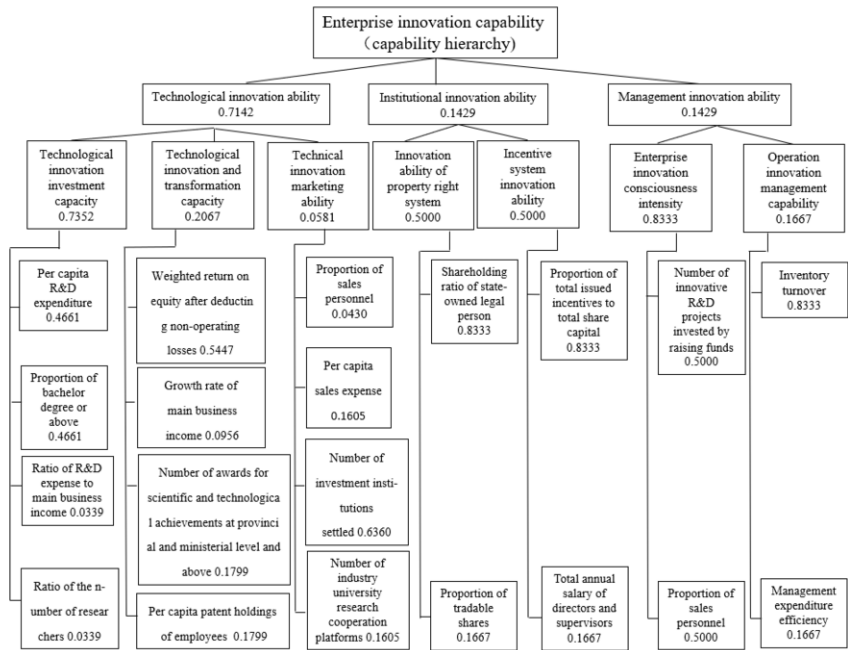
Figure. 3 Index weight based on improved AHP method

Figure 3 shows the weighting results of the enterprise innovation capability evaluation indicators. Among the three primary indicators, technological innovation capability (0.7142) is higher than the institutional innovation capability (0.1429) and the management innovation capability (0.1429), indicating that improving the enterprise's technological innovation capability is still an important path to support enterprises to realize innovation strategy.

The assignment weight of operation innovation management ability (0.1667) reflects the operation of economic resources and inventory management level of the enterprises after investing management expenses, the enterprise innovation consciousness intensity (0.8333) reflects the sustainability of the development of enterprise innovation power and the penetration intensity of enterprise innovation culture. Inventory turnover rate (0.8333) is a direct response to the level of inventory management. Inventory management ability can be said to be the third source of profits of enterprises. Poor inventory management will not only aggravate the overcapacity of manufacturing industries in Gansu Province, but also directly affect their profits. The number of innovative R&D projects raised (0.5000) reflects the importance of innovative and forward-looking thinking of the enterprises. The enterprises use the raised funds for special investment in innovative R&D projects, so as to give full play to the capital link between the enterprises and strategic investors, so as to strengthen the coordination in R&D, capital, business and other related fields.

The property right system innovation ability (0.5000) and the incentive system innovation ability (0.5000) are the core kinetic energy to optimize the internal and external relations of enterprises and coordinate the allocation of factors. The innovation

ability of incentive system (0.5000) reflects the importance of incentive system for the cultivation of innovative talents and teams of the listed companies. Compared with the annual salary incentive, equity incentive can better reflect the advantages of long-term incentive mechanism. Therefore, the assignment weight of the proportion of the total issued incentive to the total share capital (0.8333) is significantly higher than that of the total annual salary of directors and supervisors (0.1667); The shareholding ratio of the state-owned legal persons (0.8333) and the proportion of circulating shares (0.1667) measure the innovation ability of the property right system from two perspectives: property right structure and equity liquidity.

4. Evaluation of Enterprise Innovation Ability - A Case Study of 30 Listed Companies in Gansu Province

Manufacturing has been the most active field of technological innovation for a long time. Seizing the commanding heights and core technologies of manufacturing global value chain has become the only way to realize national rise and regional economic take-off. As the most dynamic micro-subject in regional economic development, listed companies have become the backbone of economic growth.

Based on this, it is planned to explore from the following aspects: Firstly, taking 30 listed companies in Gansu Province from 2016 to 2020 as the research object, the overall innovation ability of the research is carried out, and the innovation ability level of listed companies is comprehensively analyzed; Secondly, combined with the industry attributes, industry characteristics and disclosure of relevant information of listed companies in Gansu Province, the innovation ability is quantified to provide appropriate innovation ability development path for listed companies in Gansu Province.

4.1 Gansu Listed Company Basic Situation Overview

4.1.1 Industry distribution

By October 2021, excluding ST, *ST status and delisted companies, Gansu province has a total of 30 listed companies, including Qilian Mountain, Shouhang High-tech, Asia-pacific Industry, 20 listed companies are affiliated to the manufacturing industry, accounting for 66.67% of the total number of listed companies in Gansu Province. The remaining 10 listed companies are distributed in six industries, including electricity, professional and technical services, wholesale and retail, mining and culture media. In 2020, 10 listed companies in Gansu province are listed on the list of high-tech enterprises recognized by the Department of Science and Technology of Gansu Province, accounting for only 33.33% of the number of listed companies in the province, among which high-tech manufacturing enterprises account 23.33% of the total number of listed companies and 14% of the total number of manufacturing enterprises in the province.

4.1.2 Distribution of registration places

"What kind of better city innovation?" is always the prime focal point of the political attention as regards technology and urban development. Wang Yangjie, MaYingLin (2020) empirically analyzed the relationship between the city administrative level and the enterprise innovation theory hypothesis by using China's industrial enterprise survey data and statistical data[29]. The research shows that the innovation performance of enterprises is highly correlated with the administrative level of the city where they are located, and the enterprises located in the core development region can make better use of the high-quality resources within the region to achieve high-speed innovation development. A total of 19 listed companies in Gansu province are registered in Lanzhou, the provincial capital, while the remaining 11 listed companies are registered in six prefecture-level cities namely, Jiuquan, Tianshui, Baiyin, Longnan, Jiayuguan and Wuwei. Gansu province is an underdeveloped region in the west, and some prefecture-level cities and autonomous regions are facing serious low-level development than Lanzhou, and their economic development modes are restricted to varying degrees.

At present, the business activities of the listed companies in the province are mainly concentrated in Lanzhou and Belarus, and the innovation leading role of "Lanbai Self-created Zone" and "Lanbai Experimental Zone" is further highlighted thus, exacerbating the regional development gap in the province. In the face of unbalanced urban economic development, in order to break the long-term development deadlock, the management of listed companies should put innovation at the core of the overall development, and all industries should break through the bottleneck of various resources through technological docking and communication between enterprises, so as to achieve high-quality innovative development of enterprises. At the same time, in order to slow down the regional development trend of "low in the east and weak in the south", Gansu province should promote the regional innovation development of Jiuquan, Tianshui, Jinchang and Zhangye and further highlight the innovation advantage of Hexi region on the basis of maintaining the "medium strong and high in the west" during the "14th Five-year Plan". Through continuous construction of innovative cities, more cities and states in the province are approaching the goal of realizing the construction of innovative cities, and ultimately provide a better survival and develop environment for enterprise innovation.

4.1.3 R&D inputs and outputs

The number of patents of the listed companies directly indicates the strength of the individual company's innovation ability, which to a larger extent reflects in the output of innovation research results. According to the data retrieved by the China Patent Information Center of the State Intellectual Property Office, there is a wide gap in the independent innovation ability of the listed companies in Gansu Province. The listed company with the largest number of patents is JISCO Hongxing, which owns 1593 patents, accounting for 26.93% of the total number of patents owned by the listed companies in Gansu Province. While the wholesale and retail industry namely, Lanzhou Minbai and Guofang Department neither invested in R&D nor hired any technical R&D personnel.

4.2 Evaluation of Innovation Ability of Listed Companies in Gansu Province

Innovation ability evaluation index system of the listed companies in Gansu province is formed by positive analysis indicators. In order to ensure the index and have good comparison between the maximum eliminate index units and dimensional difference influence on research, this article on the basis of the original data compiled up a cumulative frequency distribution of three indicators, let the cumulative frequency r_{ij} of the third level index of item j of the i th listed company.

Calculate the score of the i th listed company under the evaluation index system of innovation ability of Listed Companies in Gansu Province by using the following equation.

$$S_i = 100 \times \sum_{j=1}^{n} W_j \times r_{i,j}$$

4.2.1 Measurement results of innovation capability

Table 11 reveals the evaluation score and the ranking of different innovation abilities of all the 30 listed companies in the study.

Table 11 Evaluation score and ranking of innovation ability of Listed Companies in Gansu Province

Name	Technological innovation ability		Institutional innovation ability		Management innovation ability		Composite scores	Ranking
	Score	Ranking	Score	Ranking	Score	Ranking		
LKGXco,ltd	81.12	1	80.84	1	78.57	3	80.43682	1
HMKJco,ltd	81.07	2	56.27	23	76.93	4	73.06397	2
HTKJco,ltd	75.30	3	66.99	11	59.37	17	68.60024	3
ZHTBco,ltd	74.37	4	61.37	17	69.34	8	68.41286	4
LSRFco,ltd	74.12	5	61.33	18	52.37	24	65.89563	5
SHGKco,ltd	72.11	6	60.51	19	72.66	5	65.68339	6
ZYMCco,ltd	66.48	7	45.52	29	85.97	2	64.96502	7
DYJSco,ltd	66.04	8	61.39	16	69.76	6	64.74459	8
FCZYco,ltd	65.28	9	70.25	8	50.63	25	63.78027	9
YTSYco,ltd	65.25	10	47.14	28	61.06	15	63.49804	10
DZCMco,ltd	64.24	11	59.64	20	64.06	13	62.32742	11
DHZYco,ltd	63.06	12	61.53	15	65.74	12	61.03982	12
FDTSco,ltd	59.85	13	63.18	14	60.84	16	61.02761	13
QLSco,ltd	58.42	14	75.72	3	68.19	9	60.74933	14
LSZZco,ltd	58.08	15	68.46	9	59.10	19	60.22783	15
SFSNco,ltd	56.56	16	70.42	7	66.01	11	60.12376	16
GSDTco,ltd	55.92	17	66.89	12	69.47	7	58.96015	17
CCDGco,ltd	51.12	18	55.39	24	49.23	27	58.6514	18
JHJco,ltd	49.07	19	66.79	13	49.90	26	57.87399	19
ZXJYco,ltd	48.22	20	75.36	4	61.20	14	55.99208	20
MGGFco,ltd	44.88	21	57.02	21	87.25	1	54.19665	21
JGHXco,ltd	44.31	22	75.23	5	53.04	23	53.95715	22
YSJTco,ltd	41.97	23	57.02	22	66.25	10	51.88404	23
JYMDco,ltd	41.85	24	76.51	2	56.62	21	51.75505	24
GZXco,ltd	41.73	25	50.72	26	37.29	30	51.05716	25
BYYSco,ltd	39.12	26	68.28	10	37.99	29	49.86853	26
LSGCco,ltd	37.66	27	74.37	6	59.27	18	49.37064	27
GFJTco,ltd	36.14	28	53.75	25	54.34	22	46.17898	28
HTJYco,ltd	34.72	29	45.25	30	58.96	20	45.57054	29
LZHHco,ltd	29.69	30	49.97	27	40.31	28	44.96227	30

4.2.2 Analysis of innovation capability

(1) Technological innovation ability: Listed companies in the brewing manufacturing industry and wholesale and retail industry represented by Lanzhou Huanghe River, Huangtai liquor industry, Guofang Department and Lishang Guochao rank the lowest due to the problems of insufficient investment in innovation, R&D and low efficiency in achievement transformation. The specific manifestations are: zero investment in enterprise R&D funds, no registered patents and low proportion of R&D technicians. Mining enterprises (mining auxiliary) and manufacturing enterprises (special equipment and medicine) namely, Heimer technology, Lanke High Tech and Longshenrongfa rank high in the technological innovation ability due to continuous investment in scientific and technological innovation thereby shifting to high-tech manufacturing enterprises. In 2020, there were only 9 listed companies recognized as high-tech enterprises by Gansu Provincial Department of Science and Technology, of which the belongs to the field of cultural media and the rest 8 are manufacturing enterprises.

(2) Institutional innovation ability: On the basis of the large weight assigned to the innovation ability of the incentive system, Lanke High Tech and Jingyuan Coal Power rank first and second in terms of absolute advantages in the total annual salary of the directors and supervisors and the proportion of the total issued incentives to the total share capital. Among the listed companies only seven firms implement the equity incentive plan and Lishang Guochao ranks first with 2.87% of the total incentive, which reflects that these enterprises use the positive incentive policy to inspire its employees so as to ensure the stability of the talent team and the gradient construction of talent reserve. In terms of the innovation ability of property right system, compared with the manufacturing enterprises with 100% circulating shares such as Lanke Hi-Tech and Shangfeng cement, the proportion of Gan consulting circulating shares is only 46.95%, which restricts the development of the enterprise due to the weak circulation of shares. A total of 18 enterprises are held by state-owned legal entities. The diversification of investors can stimulate the innovation vitality and passion of enterprises on the basis of relatively dispersed equity.

(3) Management innovation ability: Taking the first ranked Mogao shares as an example, in recent years, it has not only increased the investment in management expenses, but also invested the raised funds in innovative R&D projects, which has significantly improved the efficiency of patents. In com\parison to the other three listed companies in the brewing manufacturing industry, it has shown a strong sense of innovation and a high level of operation and management ability. Listed manufacturing companies represented by Lanke Hi Tech and Manor ranch also performed well in management innovation. With the adjustment of the global industrial chain, traditional manufacturing enterprises alleviate overcapacity by improving inventory management level, and finally improve the profitability and broaden financing channels.

5. Validity Test of Index System

The evaluation criteria of the rationality of the index system include the independence, redundancy and universality of the index system. Referring to the ideas of Fu Yun and Liu Yijun (2009), the redundancy degree is used to measure the independence and redundancy of the index system while, the sensitivity degree is used

to measure whether the index system has reliable spatial universality[30].

5.1 Index System Redundancy Test

The redundancy of the index system is used to measure the independence of the index system and the redundancy of the index. Set the correlation coefficient matrix of the index system X^p as R^p $(p = 1, 2, ..., n)$, where p represents the p th index system.

$$R = \begin{bmatrix} 1, & r_{12}, r_{13}, \ldots, r_{1n} \\ r_{21}, & 1, r_{23}, \ldots, r_{2n} \\ \ldots & \ldots & \ldots \\ r_{n1}, & 1, r_{n3}, \ldots, r_{nn} \end{bmatrix}$$

The redundancy calculation formula of RD is given by:

$$RD = \frac{\sum_{i=1}^{n_p} \sum_{j=1}^{n_p} |r_{ij}| - n_p}{n_p^2 - n_p}$$

The RD critical value is set to 0.5. It is generally believed that when RD is less than or equal to 0.5, the indicator system passes the redundancy test; otherwise, the indicator system needs to be modified. SPSS25.0 was used to test the correlation of indicators, and the sum of the absolute correlation coefficient of each indicator was calculated to be 93, RD=0.192 < 0.5, and the redundancy did not exceed the critical value, so there was no need to adjust the indicator. Meanwhile, the simplification and independence of the indicator system were demonstrated.

5.2 Sensitivity Test of Index System

Enterprise innovation ability evaluation result is the ability of evaluation objects, evaluation standard, evaluation model and index weight under the joint action of multiple factors. In index system of sensitivity analysis there is an error in the process of inspection evaluation method because the evaluation result is influenced by the kind of method used to measure the universality of the index system in evaluation of different types of objects. For a set of evaluation index system, the sensitivity of evaluation result X_i is defined as:

$$SD_i = \frac{\Delta V(Xi)/V}{\Delta Xi / Xi}$$

Sensitivity of index system is represented as:

$$SD = \frac{1}{n_p} \sum_{i=1}^{n_p} SD_i$$

The physical meaning of index system sensitivity is very clear, indicating the relative change of evaluation results caused by each change of unit relative amount of single or multiple indexes in the index system. From the perspective of the evaluation of index system rationality, the larger the $|SD|$ more is the sensitive index system, and the worse is its universality. A 1% change in the index value of the index system allows

a system error of no more than 5%, so the $|SD|$ should not exceed 5. When $SD = 0.976$, the absolute value is far less than 5, indicating that the index system has strong universality. On the other hand, when comprehensive $RD = 0.192$, it is considered that the evaluation index system of enterprise innovation capability has passed the sensitivity test and has strong universality and high reliability.

6. Conclusion and Enlightenment

On the basis of scientific, operable and comparable, this paper combs and summarizes the existing literature, demonstrates that the innovation ability of listed companies is a comprehensive ability, constructs the enterprise innovation ability evaluation index system and enterprise innovation ability evaluation model from the three levels of technological innovation ability, institutional innovation ability and management innovation ability, and uses the improved analytic hierarchy process to determine the weight of indicators at all levels, It provides a scientific measurement standard for enterprises to evaluate their own innovation ability, provides an evaluation basis for provinces, cities (prefectures) to identify the scientific and innovative attributes of enterprises, and provides a reference for investors to make reasonable investment decisions. At the same time, limited by the length, there are few literatures to test the effectiveness of the innovation capability evaluation index system after completing the construction. This paper uses the rst evaluation method to verify the operability and applicability of the enterprise innovation capability evaluation index system.

In view of the upcoming research, the author believes that some descriptive indicators can appropriately be introduced into the index system, and a five-level quantitative table is envisaged to be used to score them, so as to eliminate the adverse impact of the unavailability of the index data on the accuracy of the evaluation results to a greater extent. Meanwhile, the relevant departments should strengthen the implementation of the new securities law, revise the management measures for information disclosure of listed companies, and form an information disclosure rule system guided by the needs of investors, It helps to build a more detailed index system.

References

[1] M.Dougson, R.Roswell.Innovation focus:industrial innovation manual, translated by Chen Jin, Beijing: Published by Tsinghua University; c2000.p. 87-88.

[2] Freeman C.The Economics of Industrial Innovation,New York:The MIT Press; c1971.p.37-65.

[3] Jan Fagberg, David Molly, Richard Nelson.Oxford innovation manual, translated by Liu Shuolin, Beijing: Intellectual Property Press; c2009.p.5-28.

[4] Mansfield E.The economics of technological change, New York: W. W. Norton and Company; c1971.

[5] Mensch G.The Stalemate in Technology, Cambridge Massachusetts:Ballinger Publishing Company; c1979.p.241.

[6] Rammer C, Czamitzki D. Spielkamp A. Innovation Success of Non-R&D-Performers: Substituting Technology by Management in SMEs.Small Business Economics, 2009; 33(1):35-38.

[7] Cohen W M. Richard C L. Mowery D.Firm Size and R&D Intensity: A Re-examination. Journal of Industrial Economics.1987;35(4): 543-565.

[8] Galende J, Suarez I A.Resource-based analysis of the factors determining a firm's R&D activities. Research Policy.1999; 28(8): 891-901.

[9] Arundel A, Bordoy C, Kanerva M. Neglected innovators: How do innovative firms that do not perform R&D innovate? Results of an Analysis of the Innobarometer.2008; 23(4):9.

[10] Kirner E. Kinkle S. Jeager A.Innovation paths and the innovation performance of low-technology firms: An empirical analysis of German industry. Research Policy. 2009 Jan;38(3):447-458.

[11] ChangXiuze.Three theoretical pillars of China's enterprise system innovation. Research on Modern Enterprise System.1994; 4(1): 8.

[12] Ikujiro Nonaka.,&Hirotaka Takeuchi.(2006).Enterprises that create knowledge: the driving force for continuous innovation of Japanese and American enterprises,Beijing:Intellectual Property Press.c200618.

[13] WangDazhou, GuanShixu. Research on the interaction mechanism between enterprise technological innovation and institutional innovation.Dialectics of nature newsletter.2001 Jan; 23(1):45.

[14] Duan Yunlong.Theoretical review and research prospect of the interaction between institutional innovation and technological innovation. Science and technology management research.2009 Dec;12(1):36.

[15] Fu Jiaji.Facing the challenge of knowledge economy,what should we do on technological innovation?China soft science. 1998 Jul;7(1):36-39.

[16] Chesbrough H, Vanhaverbeke W, Bakici T, Lopez-Vega H.Open innovation and public policy in Europe. London: Science Business Publishing.

[17] Chen Jin. Theoretical basis and connotation of collaborative innovation. Scientific research. 2012 Feb;30(2):162-163.

[18] Gadaf Rexhepi, Hyrije Abazi, Amir Rahdari, Biljana Angelova.Open Innovation Models for Increased Innovation Activities and Enterprise Growth. Open Innovation and Entrepreneurship. 2019 Jun;1(1):45-46.

[19] XieRuoqing, ZhuPingfang.Research on the evaluation of innovation ability of Chinese industrial listed companies. Social sciences. 2020 Feb;2(5):41.

[20] Zhang Zhihe, Wang Yanwei, Yan Liang, Xu Xiaoqing.Research on the evaluation of innovation capability of listed companies-data from 41 listed companies in Shan xi Province. Scientific research management. 2016 Mar;37(3): 87-89.

[21] Li Qun, Ling Kang.Fuzzy theory comprehensive evaluation of enterprise technological innovation ability index system.Practice and understanding of mathematics.2004 May;34(5),41-46.

[22] ZhaoWenyan, ZengYueming.Construction and design of innovation capability evaluation index system of innovative enterprises. Research on science and technology management.2012;31(1):15-18.

[23] Wang Mengqiu, Ma Lu. Construction of evaluation index system for innovation capability of innovative enterprises. Business culture. 2012 Oct,10:393.

[24] Saaty T L.A scaling method for priorities in hierarchical structures. Journal of mathematical psychology.1997;15(3):234-281.

[25] Xu Liping, Jiang XiangRong, Yin Chong. Research on evaluation index system of enterprise innovation ability. Science research Management. 2015 Jan;36(1):124.

[26] Luo Zhengqing, Wang Tongxu, Zhou Hongnian.Discussion on the indirect giving method of judgment matrix in analytic hierarchy process. Systems engineering.1993;3:34-41.

[27] Sang Song, Lin Yan, Ji ZhuoShang.The improved AHP method is used to demonstrate the ship form scheme MCDM. Journal of Dalian University of Technology.2002 Mar;42(2):205-207.

[28] Cao Yupeng, Wang Zhijie, Hu Yong wen. Application of improved analytic hierarchy process in the evaluation of College Students' comprehensive quality Light industry technology. Light industry technology.2018 34(3):53-54.

[29] Wang Yangjie, Ma Yinglin. The impact of urban administrative level on enterprise innovationperformance-An Empirical Analysis Based on the data of Chinese Industrial Enterprises. Technical economy.2020 Aug;39(8):61-65.

[30] Fu Yun, Liu Yijun. RST evaluation method and application of index system effectiveness. Managementreview.2009 Jul;7(1):92-94.

Collaborative Filtering Algorithm Based on Item Popularity and Dynamic Changes of Interest

Xuan Zhang[a,b], Kai Su[a,1], Feng Qian[a], Yanru Zhang[c], Kan Zhang[a]

[a]*Department of Management Engineering and Equipment Economics, Naval University of Engineering, Wuhan 430033, China*
[b]*Naval Aeronautical University, Yantai 264000, China*
[c]*Bejing Goldwind New Energy Trade Co.LTD, Beijing 102600, China*

Abstract. The traditional collaborative filtering algorithm does not consider the influence of item popularity in similarity calculation, and the prediction score does not consider the influence of time on the change of user interest, resulting in inaccurate similarity calculation and single recommendation result. To solve these problems, this paper improved the traditional similarity calculation method by combining the item popularity penalty coefficient, improved the recommendation diversity of the algorithm, and integrated the time factor into the prediction method to solve the problem of interest attenuation. Experiments on the 100K and 1M data set of Movielens show that the improved algorithm effectively improves the accuracy and coverage of recommendations.

Keywords. Recommendation system; Collaborative filtering; Item popularity; Dynamic interest change; Time function.

1. Introduction

Recently, Customers cannot quickly find satisfactory products in the face of excessive information, resulting in poor online shopping experience for users [1]. Recommendation system can explore potential interests and hobbies by analyzing the historical behavior information of users and make targeted personalized recommendations to users without specific the needs of users [2].

Collaborative filtering is considered to be one of the most promising and widely used recommendation algorithms, which is used to help users finding commodities they may like [3, 4]. Traditional collaborative filtering methods calculate similarity only based on user grade [5]. However, with the increase of the number of users and commodities, users are more easily to find and buy those popular commodities, causing the asymmetry of score data. In this case, the similarity calculated is not accurate, and the popular items in the generated recommendation list almost account for the majority, which is not conducive to the individuation and novelty of the recommendation [6]. This situation is known as the "long tail effect" in the recommendation system [7]. In

addition, the user needs and interests will change at different stage. The traditional methods calculation methods for all score right, unable to identify the dynamic changes of the user's interests which called "drift" [8].

In this paper, a collaborative filtering algorithm based on item popularity and dynamic change of interest is proposed. Firstly, the item popularity was integrated into the similarity calculation method, and the popularity penalty function was defined through item popularity and item popularity differences to improve the diversity of recommendation results. Secondly, according to the different behavior characteristics of users, the time decay function is defined to weaken the contribution of old data to the predicting results and make the final recommendation result more accurate. The experimental results on Movielens data set show that the proposed algorithm can not only improve the recommendation accuracy, but also improve the diversity of recommendations.

2. Related work

In recent years, collaborative filtering based recommendation algorithms have been widely used to solve personalized recommendation in the field of e-commerce, among which computing similarity and predicting score are the most important two parts. Item-based Collaborative Filtering algorithm (IBCF) calculates the similarity between items according to users' scores, and firstly constructs a scoring matrix based on users' scoring information. Based on the constructed scoring matrix, similarity calculation method was used to calculate the similarity between items [9]. The commonly used similarity calculation methods include Pearson similarity and modified cosine similarity [10]. The algorithm in this paper takes modified cosine similarity as the similarity calculation method, as shown in Equation (1). Then, the top-N items with the highest similarity of target items are taken as neighbors, and the prediction score of users on target items is obtained by using the prediction formula, as shown in Formula (2).

$$Sim(i,j) = \frac{\sum_{u \in U_{ij}} (r_{ui} - \overline{r_i})(r_{uj} - \overline{r_j})}{\sqrt{\sum_{u \in U_i} (r_{ui} - \overline{r_i})^2} \sqrt{\sum_{u \in U_j} (r_{uj} - \overline{r_j})^2}} \tag{1}$$

$$P_{ui} = \overline{r_i} + \frac{\sum_{j \in N} sim(i,j) \times (r_{uj} - \overline{r_j})}{\sum_{j \in N} |sim(i,j)|} \tag{2}$$

In order to alleviate the "long tail effect" of recommendation system, scholars introduced popularity penalty factor into the algorithm. Gao et al. [11] proposed a method to punish popular items. They took the number of popular items and the proportion of the total items as punishment, and added it into the similarity calculation method. Hao et al. [12] introduced item popularity as a weight factor into similarity calculation and recommendation process to improve the reliability of user similarity calculation and influence of unpopular items in the final item recommendation process. Wei et al. [13] proposed a collaborative filtering recommendation algorithm combined with item popularity weighting, analyzed the influence of item popularity and popularity differences on similarity, and designed penalty weights for popular items exceeding the popularity threshold to reduce their contribution in similarity calculation (IPCF).

The introduction of popularity penalty weight improves the algorithm's ability to mine unpopular items, but it cannot dynamically recommend items to users. In order to solve the problem of interest dynamic change, the time factor is integrated into the algorithm. Yi [14] put forward a kind of computing time weighting algorithm to track each user's interest changes. By introducing personalized attenuation factor, the algorithm makes each score more reasonable and effective. However, the purchase cycle of each user is different, so it is difficult to provide personalized recommendation for different users. Chen [15] et al proposed a recommendation method based on dynamic time attenuation (TWCF). TWCF dynamically determines the attenuation function based on users' scoring behavior, gradually weakens the influence of old data and accurately predicts future users' preferences. Song et al. [16] proposed the time-weighted based information recommendation algorithm, where the users set, time, tag set and goods resources are utilized to calculate the tag feature vector to predict the user's preferences. After time function is added into the recommendation algorithm, the problem of dynamic change of user interest is solved to some extent.

3. Collaborative filtering algorithm based on item popularity

3.1. Normalization of item popularity

In the recommender system, item popularity is expressed as the number of user evaluations. The more times an item is evaluated, the higher its popularity will be. Popular items are more likely to be selected and evaluated by users due to their popularity or high cost performance, and two popular items are more likely to be scored by the same user at the same time. When using traditional similarity to calculate the similarity of two popular items, the calculated similarity is higher, but this does not mean that popular items are similar to other items.

Due to the large difference in popularity between items, there will be a large difference in numerical value in calculation, and the result will be greater than 1 in the subsequent calculation of attribute weight function. Therefore, this paper normalized The Times of user evaluation, as shown in equation (3), to keep its value range at [0,1], so as to reduce data deviation. Where, popitem (i) refers to the number of times that item i has been evaluated, popmax refers to the number of times that the most popular item has been evaluated, and popmin refers to the number of times that the least popular item has been evaluated.

$$Pop(i) = \frac{popitem(i) - popmin}{popmax - popmin} \qquad (3)$$

3.2. Deviation of item popularity

In this paper, the absolute value of the difference in item popularity is defined as the difference in item popularity. The smaller the difference in popularity between the two items, the closer the popularity of the two items. Items with small differences in popularity are similar in popularity and other aspects. Such items are more likely to be discovered and purchased by the same user. Therefore, there are more users who have jointly evaluated these two items, and the calculated similarity will be high. The difference in prevalence between item I and J is shown as follows:

$$popBias(i,j) =| \ Pop(i)- Pop(j)| \qquad (4)$$

3.3. Weight of popularity

Items with high popularity have more common scores with other items, popular items are easier to be selected and evaluated by users, their similarity with other items is generally high, and such items are subject to greater punishment. Therefore, the popularity of items is positively correlated with the weight of punishment. Popularity differences will also affect the calculation of similarity. The smaller the difference in popularity between the two items, the greater the possibility of them being found and purchased by user, causing the similarity being evaluated too high. Based on the above analysis, combined with the popularity of the item and the differences in popularity, the popularity penalty weight function is proposed:

$$Weight(i,j) = \frac{lg2 \times Pop_i}{lg(2 + Popbais_{i,j})} \qquad (5)$$

Pop (i) is the normalized popularity of item i, and PopBais (i, j) is the difference in popularity between item i and item j. Since the prevalence difference between items is large, the numerical value will have a great influence on the penalty weight, so lg function is introduced to reduce the numerical influence of the prevalence difference. When PopBais (i, j) = 0, the prevalence difference is the smallest. Combining the popularity penalty weight function with the traditional similarity calculation method, the improved item similarity calculation formula is as follows:

$$Sim(i,j) = \frac{\sum_{u \in U_{ij}} [(r_{ui} - \overline{r_i})weight(i)][(r_{uj} - \overline{r_j})weight(j)]}{\sqrt{\sum_{u \in U_i} [(r_{ui} - \overline{r_i})weight(i)]^2} \sqrt{\sum_{u \in U_j} [(r_{uj} - \overline{r_j})weight(j)]^2}} \qquad (6)$$

4. Collaborative filtering algorithm based on dynamic temporal interest change

Users' purchase interest and memory both change over time, and it is difficult for users to maintain long-term interest in a product. Generally speaking, it shows a declining trend. The recent purchase data should have a greater contribution to the prediction of preferences, so this paper gives different weights to users for each score according to the time of prediction, so as to weaken the contribution of old data to the prediction of scores. The user's interest changes dynamically with time, with more emphasis on the recent purchase interest. The characteristic of the exponential function is that it attenuates sharply first and then slows down. Therefore, this paper chooses exponential function as the attenuation function of user interest. A decay coefficient ε is introduced to slow down the decay rate. Let ε=1/T, then the time function is shown as follows.

$$f(t) = e^{-\varepsilon t} = e^{-\frac{t}{T}} \qquad (7)$$

T is the time period, and T is inversely proportional to the ε attenuation coefficient. FIG. 1 shows the curve of time function f under different T values.
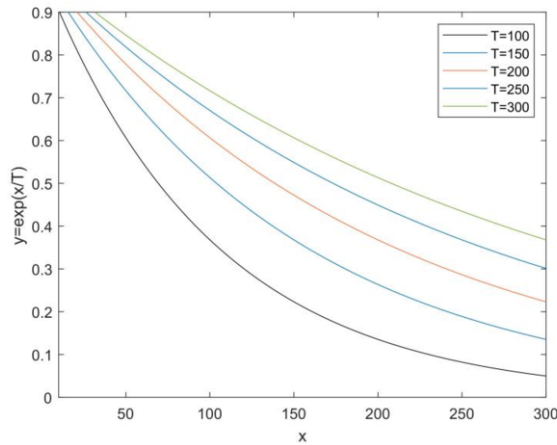
Fig. 1. Curves of f time function with different values of T

The larger T is, the slower the change of time function is and the smaller the contribution of historical data is. The value of T determines the attenuation rate of f to historical data, and an appropriate parameter T should be selected to accurately predict users' future preferences so as to improve the performance of the algorithm. In the recommender system, the decay rate of historical data should be determined by the purchase behavior of each user. In a period of time, if a user has a long and frequent purchase cycle, all the goods purchased in the purchase cycle can provide more accurate data support for predicting preferences. The old data should be decayed slowly and a higher value T should be assigned to the time function. In this case, different T values can be selected according to the shopping cycle of each user, and the purchase cycle of user U can be defined as $T_u = t_{max} - t_{min}$. At this time, the time function is shown in Formula (8), where T_{MAX} is the earliest time when users purchase goods within a period of time, and T_{MAX} is the latest time when users purchase goods within this period. T is the time when the user buys the target item.

$$f(t) = e^{-\frac{t - T_{MIN}}{T_{MAX} - T_{MIN}}} \tag{8}$$

In addition, the buying habits of users vary, and even the same users have different attitudes towards different things. Therefore, this paper classifies items into instantaneous interest items, general interest items and long-term interest items according to users' purchasing behavior. If the user's interest in a certain item lasts for a long time, it can be considered that the user has a long-term interest in this item. If there is only one purchase record, it can be considered that the user has only transient interest in such items. Anything in between is called general interest. The k-means clustering method was used to cluster commodities according to user rating data. The purchasing frequency α was defined as the rating times of each commodity category by users, and the frequency threshold θ was set. The purchase frequency greater than the threshold θ is classified as the long-term interest of users, while the purchase frequency less than the threshold is classified as the short-term interest of users. The liking degree of long-term interest products does not decrease with time in the interest cycle of users, so the time function has no weakening effect on the score of such products. However, for commodities of general interest and instantaneous interest, users' interest in them

will gradually weaken over time, so the contribution of their scores should be weakened when predicting user preferences. On this basis, redefine the time function:

$$f(t) = \begin{cases} 1 & if \ \alpha > \theta \\ e^{-\frac{t-T_{MIN}}{T_{MAX}-T_{MIN}}} & if \ \alpha <= \theta \end{cases} \tag{9}$$

It can be seen from Equation (9) that, for commodities purchased more frequently by users, the time function does not reduce the contribution of scoring, while for commodities purchased less frequently, the time function reduces its contribution according to the purchasing cycle and scoring time of users when predicting scoring. Combined with the time function, the prediction formula is as follows:

$$P_{ui} = \bar{r}_i + \frac{\sum_{j \in N} sim(i,j) \times [(r_{uj} - \bar{r}_j) \times f(t)]}{\sum_{j \in N} |sim(i,j)|} \tag{10}$$

5. Experimental Analysis

5.1. Experimental data set

In order to verify the effectiveness of the algorithm, several experiments are carried out on Movielens 100K and 1M data sets including the ratings of 1682 movies by 943 users. The ratings are divided into five grades from 1 to 5, and each score has a definite scoring time. In this paper, the five-fold crossover method is adopted to divide the data set. The 100K and 1M data sets are randomly divided into five parts, four of which are randomly selected as training sets, and the remaining one as test set. Five data sets are divided into 1-5 respectively, and the average value is taken as the experimental result.

5.2. Evaluation indicators

In this paper, accuracy and coverage are taken as the evaluation indexes of the algorithm. Accuracy is measured by the difference between the predicted score value and the real score, as shown in Equation (11). Coverage rate is a measure of the proportion of recommended items in the total collection of items in the recommendation system, which can effectively reflect the diversity and novelty of recommendations. The formula is shown in Equation (12).

$$MAE = \frac{1}{N} \sum_{i=1}^{m} |p_i - q_i| \tag{11}$$

$$coverage = \frac{\left| \sum_{u \in U} R(u) \right|}{|I|} \tag{12}$$

5.3. Comparison algorithm

Table 1 lists the algorithms used for experimental comparison, including the traditional item-based collaborative filtering algorithm, the recommendation algorithm combined with item popularity, the time-fused collaborative filtering algorithm and the algorithm proposed by this paper.

Each algorithm was tested on Movielen-100K and 1M data sets, and MAE and coverage were compared under different numbers of neighbors.

Table 1. Comparison algorithm description

The algorithm name	Item popularity	Time	Algorithm description
Traditional collaborative filtering algorithm(IBCF)			Unimproved item-based collaborative filtering algorithm
Time - based collaborative filtering algorithm(TWCF)[15]		√	Collaborative filtering algorithm combined with time optimization prediction method
Collaborative filtering algorithm based on item popularity(IPCF)[13]	√		A collaborative filtering algorithm was proposed to improve the similarity calculation method based on item popularity
Collaborative filtering algorithm based on dynamic changes of item popularity and interest(IPTWCF)	√	√	We propose a collaborative filtering algorithm combining popularity and time optimization

(1) MAE comparison

Figure 2 and 3 show the MAE comparison results. Obviously, the MAE of the algorithm proposed by this paper is the lowest with different number of neighbors, where the MAE of the traditional collaborative filtering algorithm is the highest. The time-based collaborative filtering algorithm and the popularity-based collaborative filtering algorithm start from the dynamic changes of item popularity and user interest respectively, and combine the popularity penalty weight and time function to optimize the similarity and score prediction respectively. In 100K and 1M data sets with different neighbor numbers, the MAE values of the two algorithms have little difference, and are generally lower than the traditional algorithm. At the same time, this paper improved the algorithm by combining the item popularity and user interest changes, redefined the popularity penalty function and time function, optimized the similarity calculation method and prediction method, and improved the recommendation accuracy. Compared with the MAE based on popularity-based collaborative filtering and time-based collaborative filtering, the recommendation accuracy of the proposed algorithm is higher. Therefore, by adding the time function and popularity penalty function defined in this paper, the similarity between items is more reasonable and preferences can be reasonably predicted according to the dynamic changes of user interests.
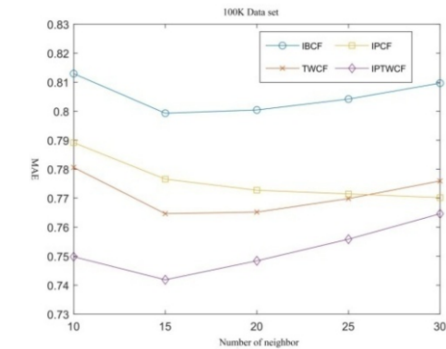

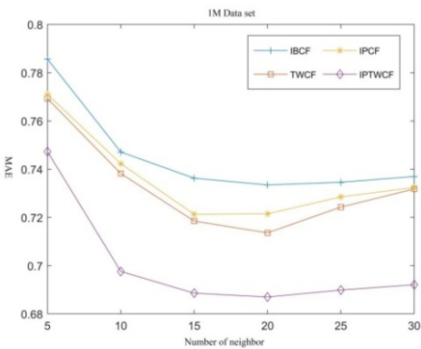**Fig. 2.** MAE of different algorithms on Data set 100K   **Fig. 3.** MAE of different algorithms on Data set 1M
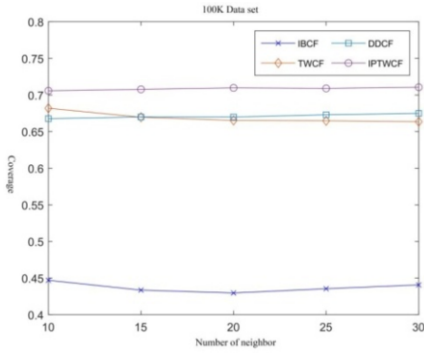
(2) Comparison of coverage

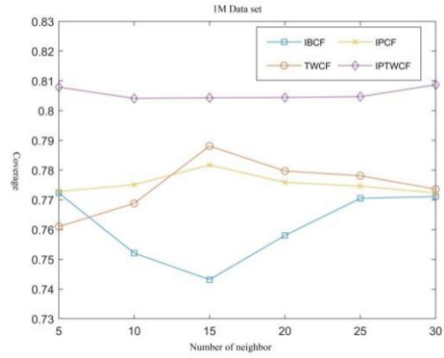**Fig.4.** Different algorithms Coverage of Data set 100K   **Fig. 5.** Different algorithms Coverage of Data set 1M

Figure 4 and 5 show the coverage comparison results. As can be seen from the comparison test results of the coverage of the two data sets, the coverage of the traditional algorithm is generally low. This is because the items with high popularity are generally similar to other items, and the popular items recommended to users account for the majority, while the number of popular items only accounts for a small part of the total. Therefore, the range of items recommended by the traditional collaborative filtering algorithm is relatively narrow. The collaborative filtering algorithm based on item popularity assigns penalty weight to items with different popularity when calculating similarity, which weakens the influence of popularity on item recommendation. The results show that the coverage of collaborative filtering algorithm based on item popularity is higher than that of traditional collaborative filtering algorithm and time-based collaborative filtering algorithm, indicating that the improvement of popularity can effectively improve the coverage of recommendations. In this paper, based on the collaborative filtering algorithm of popularity and time, the popularity penalty weight is optimized and the recommendation weight of popular items is weakened, thus the potential interests of users are truly explored. Unpopular items can also be recommended to users. As can be seen from the figure 4 and 5, the coverage rate of the algorithm in this paper is the highest under the number of neighbors, indicating that the algorithm in this paper can effectively improve the coverage rate of recommendations and effectively mine the potential interests of users.

6. Conclusions

This paper proposes a collaborative filtering algorithm based on the dynamic change of item popularity and interest, which integrates the item popularity into the similarity calculation method to solve the problem of high similarity of popular item. At the same time, according to the behavior characteristics of each user, a time function is added to the prediction formula to reduce the contribution of historical data to prediction preference. While improving the accuracy of recommendation, the proposed algorithm can effectively mine and recommend the unpopular items in the data set, improve the coverage of recommendation, alleviate the problem of "long tail effect" in the recommendation system, and improve the quality of recommendation.

However, there are also many areas to be improved. In the future work, we will further study the impact of different activity and scoring habits on users' interests, and provide personalized recommendations according to different users' living habits and shopping characteristics.

References

[1] Bresler G, Karz and M.Regret Bounds and Regimes of Optimality for User-User and Item-Item Collaborative Filtering[J]. IEEE Transactions on Information Theory, 2021, PP(99): 1-1.

[2] Meng D F, Liu N, Li M X, et al. An Improved Dynamic Collaborative Filtering Algorithm Based on LDA[J]. IEEE Access, 2021, PP(99):1-1.

[3] Kim S, H Kim, Min J K. An efficient parallel similarity matrix construction on MapReduce for collaborative filtering[J]. Journal of Supercomputing, 2019, 75(1): 123-141.

[4] Alhijawi B, Al-Naymat G, Obeid N, et al. Novel predictive model to improve the accuracy of collaborative filtering recommender systems[J]. Information Systems, 2021, 96: 101670.

[5] Yang E, Huang Y, Liang F, et al. FCMF：Federated collective matrix factorization for heterogeneous collaborative filtering[J]. Knowledge-Based Systems, 2021, 220(1/2): 106946.

[6] Lee Y C, Son J, Kim T, et al. Exploiting uninteresting items for effective graph-based one-class collaborative filtering[J]. The Journal of Supercomputing, 2021, 77(7): 6832-6851.

[7] Manochandar S, Punniyamoorthy M. A new user similarity measure in a new prediction model for collaborative filtering[J]. Applied Intelligence, 2020.

[8] Xiao T, Shen H. Neural variational matrix factorization for collaborative filtering in recommendation systems[J]. Applied Intelligence, 2019.

[9] X Wang, Wang R, Li D, et al. QCF: Quantum Collaborative Filtering Recommendation Algorithm[J]. International Journal of The oretical Physics, 2019.

[10] Xiong H., Chen J., Liu Q., et al. Enhancing Collaborative Filtering by User Interest Expansion via Personalized Ranking[J]. IEEE transactions on systems, man, and cybernetics, Part B. Cybernetics: A publication of the IEEE Systems, Man, and Cybernetics Society,2012,42(1):218-233.

[11] Gao X, Ji Q, Mi Z, et al. Similarity Measure based on Punishing Popular Items for Collaborative Filtering[C]// 2018 International Conference on Computer, Information and Telecommunication Systems (CITS). IEEE, 2018.

[12] Hao Li-yan, WANG Jing. Collaborative Filtering TopN recommendation Algorithm based on Item Popularity [J] .Computer Engineering and Design, 2013, 34(10): 3497-3501.

[13] Wei Tian-tian, Chen Li, Fan Ting-ting, Wu Xiao-hua. Collaborative Filtering recommendation Algorithm based on Item Popularity Weighting [J]. Application Research of Computers, 2020, 37(03): 676-679.

[14] Yi D, Xue L. Time weight collaborative filtering. ACM, 2005.

[15] Chen Y C, Hui L, Thaipisutikul T, et al. A Collaborative Filtering Recommendation System with Dynamic Time Decay[J]. The Journal of Supercomputing, 2020:1-19.

[16] Song Wei-wei, Yang De-gang, Zheng Min. Research on collaborative Filtering recommendation Algorithm based on time weighted label[J]. Journal of Chongqing Normal University (Natural Science), 2016, 033(005):113-120.

Intellectual Capital and Information: Examples About Some Relationships

Óscar Teixeira Ramada[1]
Atlântico Business School, Porto, Portugal

Abstract. This research aims to know some examples of papers that relate the intellectual capital and information (the theory of) and the relationships established between both. Previous research, up to this date of 2022, has been insufficient and disjointed in a single direction. There is a lack of objective approaches (instead of subjective), and there is a lack of approaches that allow replications to reality and, above all, that make it possible to know the intellectual capital and information (the theory of) to make known an objective value, expressed in euros, as if it were other products. At the same time, there must be dynamics that make it vary over time, know its sources of change and know what makes it remain the same, raise or lower its value. Once this desideratum is reached, the real objective that materializes the intellectual capital and the information (the theory of) that underlies it is reached.

Keywords. Intellectual capital, definition, measurement methods, information (the theory of)

1. Introduction

With regard to the intellectual capital, relationships have often emerged that make it associate information (the theory of) and knowledge [1], [2], [3], [4] and [5]. Although, on the one hand, this makes sense, on the other, it is necessary to know what information (the theory of)/knowledge is involved in the business world: tangible or intangible assets? And in which activity sectors? Is this knowledge protected or is it freely available? These are some questions that are most immediately raised.

There are authors such as [6], [7], [8] and [9], who focus their research more on the foundations of the intellectual capital that are their own definition, the ways to measure and, finally, the value possessed by it.

Thus, although it is not an erroneous association, it does not clarify these basic foundations, which makes it difficult to make the association between the *intellectual capital* and *information (the theory of)/knowledge*.

This comes from not precisely defining the concept(s) of the intellectual capital and, therefore, the information (the theory of)/knowledge associated with it(s). However, [6] and [7], make a contribution towards distinguishing properly and in a way acceptable to the scientific community, a definition regarding its definition in the number of

---
[1] Corresponding Author, Óscar Teixeira Ramada, Atlântico Business School, Porto, Portugal;
Email: oscarramada@gmail.com

components and in their content. In the first author, the components are 3: human capital, structural capital and capital employed. In the second author, the first 2 components are the same, but the third one is different: customer's capital.

Following the title above, the following research question can be raised: *what do some examples of research that relate the intellectual capital to information (the theory of) say?*

In a way, these are not concepts with very marked differences. However, this idea lacks scientific proof and hence this research.

We can then say that there is a *Knowledge Gap* (*Knowledge void Gap*), which this research intends to provide some findings.

The main contribution of this research is that, as information is often a particular case of intellectual capital and this materialized in that, it is also intangible assets such as property rights, copyright and knowledge, specific and general, in particular. Therefore, there is some convergence and/or divergence of content that needs to be researched. Through some papers that relate the 2 topics, we seek to know something about this purpose and hence the aforementioned contribution.

It should be noted that the 5 papers selected for studying were obtained from an appropriate database and that resulted from the combination of the term the *intellectual capital* and *information (the theory of)/knowledge*, having obtained those referred to.

The criterion for its presentation is merely chronological, that is, from the most recent date to the least. In this way, it is possible to provide an idea of the contents covered, involving the 2 terms and their possible relationships each other.

This research is divided into 4 Sections: *1. Introduction* (where a brief introduction to the relationship, which may exist, between the intellectual capital and information (theory of) is made), *2. Literature Review* (where 5 research papers subordinated to this pair of topics), *3. Results and Discussion* (where are presented, the main issues or ideas raised by the Literature Review, and their most important discussion) and, finally, *4. Conclusions* (where the main conclusions that can be drawn from the research are shown). *References*, are the sources to do the paper.

2. Literature Review

[10], are authors who seek to explain, through the research carried out, the role of mediation of capabilities dynamics in the relations established between the intellectual capital, innovation performance and companies' communication technologies.

In the sample used by the authors, the authors selected 4483 communication technology companies located in 64 provinces of Vietnam, in a first phase to, in a second phase, limited to only 350, in all provinces in proportion to the size of the population. The method used was a survey in the context of a Likert scale, with 7 points, whose items vary between 1 = strong disagreement and 7 = strong agreement.

In the methodologies used by the authors, with regard to the measurement of the intellectual capital, 3 dimensions were considered: human capital, organizational capital and social capital. As measures of dynamic capabilities, 3 dimensions were also considered: learning, integration and reconfiguration. As measures of company performance, subjective measures were used because respondents exhibited reluctance to provide objective measures. Regarding the description of data, 448 surveys were distributed to CEOs, project managers and other executives of information technology companies in Vietnam, and 350 responses were received. Note that all participants were

male. In terms of educational qualifications, respondents with only a vocational school were 13, a Bachelor's degree were 267 and a Master's degree, 71. In terms of age at 20 years old, respondents were 10, with 30, there were 255, with 40, there were 81 and with more than 50, there were 5. In the professional category, 200 respondents were active in software services, 31 in hardware, 10 in hardware manufacturing, 80 in digital media and 30 in telecommunication.

In the main conclusions reached by the authors, it is immediately underlined that research reduces the ambiguity regarding the mediation of the dynamic capabilities mechanism through the intellectual capital that improves business performance. There is evidence that learning and integration capability works as a mediation mechanism between the intellectual capital and its dimensions and the performance of companies. The accumulation of human, social, and organizational capital helps companies improve their competitive advantages and performance. It is essential to develop the learning capabilities to absorb information and knowledge through the practices of business iterations.

With regard to theoretical and management contributions, those referring to the understanding of the indirect effects of the dimensions of the intellectual capital on performance are noteworthy. On the other hand, the study deconstructs the dynamic capabilities in 3 dimensions and, separately, examines the effects of each one of them.

In terms of management contributions, the results show that among the dimensions of the intellectual capital, the human capital component has the greatest direct and indirect effect on business performance. Learning capabilities involves combining problem solving and coordinating strategies and may require skills and knowledge from individuals.

In the limitations and future research, the limitation of the use of data and perception is mentioned. Thus, managers may not be able to identify many examples of practical management actions based on these results. The study also does not consider dynamic environments to be a variable in which the intellectual capital and dynamic capabilities are relevant to improve performance.

[11], deal with the information management model for the intellectual capital in higher education institutions (HEI´s) in the Sultanate of Oman (capital Muscat), in the context of a theoretical quantitative approach and practical results. This research arises in the context of the urgent need, conveyed by the authors, to know what the intellectual capital is, how to develop it and, therefore, the organizations that create knowledge. They recognize that not only is this recognition important, but that it is also important to analyze its components (human capital, structural capital a customer or relational capital). It is through these 3 factors that institutions produce knowledge and disseminate it and that serve as a means through which the amount of knowledge produced in a country can be added to that already possessed.

The authors carried out an in-depth review of national and international practices related to the intellectual capital, especially in the context of HEI´s. The description in terms of methodological development involves multifaceted objectives and indicators for each of the components defined for the intellectual capital: human capital (18), structural capital (31) and relational capital (21). On the other hand, the authors resorted to techniques called point estimate of overall performance and overall performance index, to implement and differentiate the HEI´s and its performance from each other.

They concluded, in a synthetic way, that, in the long term, the HEI´s can improve their the intellectual capital by studying the obstacles that hide the achievement of good performance. In terms of results, the authors obtained good performance in some

indicators, while in others it was below average. In any case, the proposed model proved to be adequate to implement it in HEI´s to achieve the goals and, moreover, it provided some insights for them to take appropriate initiatives to apply, and enjoy, in practice, of the proposed research.

As limitations of research, there are the lack of databases of the intellectual capital indicators, the alignment between its activities and the institutional system. On the other hand, some information was only possible through the use of verbal responses, but it was not possible to use another, more reliable procedure. Finally, other indicators could have been chosen, replacing some used and used again, which is also another limitation that other future avenues of research can (and should) address.

[12] carried out research related to the extent to which women in the management of companies correspond to an increase in the disclosure of information related to the intellectual capital in Spanish companies.

The sample includes reports from all companies listed on the IBEX 35, from the years 2007 to 2011. If the reports are sustainable, then they are the greatest means of communicating business to stakeholders, increasing transparency, achieving greater social legitimacy and increasing the reputation. During the period, companies published both annual and sustainable reports. Thus, the sample source was 25 companies, over 5 years, corresponding to 125 observations. The reports were 100 of those sustainable and 25 of those that resulted in a single combination. Panel data was the type of sample used for this purpose, in order to allow a combination of times series and cross-section data, making it possible to know the effects of specific unobservable variables. The authors also resorted to content analysis.

In terms of more evident conclusions, the authors point out that, increasing the representation of women in management, improves supervision, transparency and reduces asymmetry regarding information on the intellectual capital. The results also suggest that women also improve the monitoring of corporate bodies, which also contributes to greater transparency and increased disclosure of the intellectual capital. All these conclusions are a reason to increase the number of women in the management of companies, to bring about all these effects.

[13] investigated business disclosure and the intellectual capital, in improving the quality of relations between companies and the market. This context is included in the scope of asymmetric information. Corporate disclosure and the quality of it, which is perceived by stakeholders, is a relevant topic for analysis because it can result in misunderstandings. Businesses need to prevent this reality through proper understanding of market needs. The intellectual capital plays an important role in this area. The reduction of asymmetries in the market, with regard to information, is of utmost importance.

With regard to the adopted methodology, the authors used a cross-section framework based on the theory of signals and the theory of legitimacy. This link makes an important contribution to the understanding of relevant elements to improve the efficiency of business information dissemination and to explore the extent to which intellectual capital is a key element to understand the market.

Thus, an inductive approach is underlying the methodology, which offers the opportunity to identify instruments and models capable of providing solutions to market problems. It can be seen as a particular type of qualitative approach. In addressing this perspective, the research highlights the need to shift the focus from a company's perspective to the market with voluntary corporate disclosure strategies.

In conclusion, the authors concluded that the capability of companies to obtain and defend the built competitive advantages is very related to the information that is transferred to the market. This depends on the image of this same transferred information, which can be considered one of the most efficient instruments available to companies. The intellectual capital can be considered a good starting point as it fills the gaps between companies and acquisitions of new market meanings. Improvements in this aspect also benefit from greater appetite on the part of corporate investors.

[14], focus on the usefulness of information on the intellectual capital, from the point of view of users and preparers (companies), only from the annual reports of companies listed on the Malaysia Stock Exchange, on 5 April of 2007.

With regard to the sample, it has a size of 483, with 213 being preparers (companies) and users, 160 were analysts (brokers and institutions) and 110 banks. Those who responded from the companies were CFO and accountants because they were somehow responsible for preparing the annual reports, in addition to possessing the knowledge, competence and understanding of this elaboration. To minimize the risk of a low response rate, the authors designed 3 questionnaires: 1 for CFO´s and 2 for accountants. The questionnaires were composed of 3 Sections: A, on definitions of the intellectual capital, B, on its disclosure (having been categorized into 3 categories - NC, on innovation, XC on business partnerships and HC on the education level of workers and their Well-Being) and C, on demographic issues. In Section B, there was a combination of close-ended and open-ended questions. The first ones used a 5-point Likert scale and, the second ones, the respondents were asked to write in the spaces destined for this, on subjects about the dissemination of the intellectual capital that they understood as being useful but were not included in the questionnaire.

In the main conclusions drawn by the authors that the preparers (companies) and the external users (analysts) understood the information about the intellectual capital being useful for the decision-making process. This understanding was greater in XC, followed by NC and HC. On the other hand, the results reveal that the perceptions of usefulness of the information were statistically significant. The usefulness of information on the intellectual capital has proved to be both for preparers (companies) and for their users. However, in the perceptions for both preparers (companies) and users, no differences were observed, which means that the utility is convergent both for one group and for the other.

As limitations faced by researchers, there are only 2 groups who were asked about the usefulness of information on the intellectual capital, in addition to using only one method: the questionnaire survey.

3. Results and Discussion

Some more notable results can be underlined from the literature review. Regarding innovation and business performance, it is concluded that learning and the integration of capabilities, works as a mediation mechanism between the intellectual capital and business performance and competitive advantages, and therefore, the development of learning capabilities, is essential, to capture information and knowledge, as well as problem solving and skills, from workers. The component of intellectual capital, human capital, proves to be the most important in the context of business performance.

In relation to information management, via an appropriate model for this goal, in the context of universities, the intellectual capital can be improved as long as the obstacles placed in order to achieve good performance are known.

It can also be said that, with regard to the increase in the dissemination of information on the intellectual capital, in companies with women managing them, supervision and transparency increase and decreases the asymmetry of information regarding the intellectual capital. Consequently, the presence of the female gender in the business world, is a factor that results in these effects.

In improving the quality of the relationship between companies and the respective markets where they operate, in the context of asymmetric information, the question arises of, in this way, knowing what the markets need. To this end, asymmetries must be reduced and information must be transmitted to the markets, which allows companies to build competitive advantages. The intellectual capital plays a decisive role in this area, bridging the existing gap and increasing investors interest.

In the literature review, it can still be mentioned as an outcome that the usefulness of information related to the intellectual capital, from the point of view of those who produce it (companies) and use it (analysts), is related to the decision-making processes. However, with regard to the perceptions of both, no relevant differences were found, which means that the utility proved to be convergent for both.

From the point of view of the discussion of the results, it is important to highlight the fact that learning, learning capabilities, information and knowledge, are essential, through which the intellectual capital makes it possible to achieve (business) performance and competitive advantages. In a university context, what is most evident to improve the same intellectual capital is the removal of obstacles preventing high performances. On the other hand, regarding to the dissemination of the intellectual capital, if companies are managed by women, they will be more efficient, especially, with regard to the information asymmetry. It should be underlined that its usefulness, both for those who prepare it and for those who use it, is associated with decision-making, and the perceptions of the 2 proved, to be the same.

4. Conclusions

The topic of the intellectual capital is sometimes associated with information (the theory of). This, like that, is of the intangible type, which sometimes leads to not being distinguished, at its core, in the scientific community, even if it concerns realities with features that are not common. It can be said that all the intellectual capital has something to do with information (the theory of) but not all information (the theory of) is the intellectual capital.

As the main implications of global research, it should be noted that the intellectual capital has made contributions to the recognition of the importance of defining it and applying it in concrete reality, posing difficulties for this in terms of the appropriate indicators for this purpose, raising questions relating to knowledge and information, in general.

In terms of limitations, one of the most notable is that research to date on the intellectual capital and knowledge is historical (past) and does not allow for a prospective vision (for the future) even in the present. The value assumed by information and, above all, by the intellectual capital, remains unknown, being one of the biggest gaps in knowledge that is yet to be fully addressed.

In the future avenues of research, research is to be carried out based on current information and making it possible to calculate the value of the intellectual capital that requires information to support this purpose.

Regarding the research question, *what do some examples of research that relate the intellectual capital to information (the theory of) say?* They help with information to apply it to the concrete reality (business or institutional). But, their contents are insufficient for this purpose, currently (2021-2022).

We can say that the great conclusion is that all the intellectual capital is information, specific and diversified and, above all, knowledge, whatever the form it takes (this is what allows performance, competitive advantages, among others) but, not all information is intellectual capital (e.g. information in general, about the composition of planet Earth, about geography, about a language and its basic roots). The intellectual capital, precisely, should be something that transmits knowledge, that allows civilizational progress, the well-being of countries and citizens and, above all, in a dynamic perspective, knowing the value of intangible assets, such as tangibles. There are no reasons why it should not be so. It must be noted that the value of the intellectual capital is always dynamic (and not static over time) so, knowing the factors that make it vary (increase or decrease), it should vary over time.

Therefore, the reasons for this paper be qualified in such a way that its publication is useful, lies in underlining the differences between the intellectual capital, knowledge and information (the theory of), in addition to revealing the contents of the 5 papers referred to on this topic.

References

[1] Andriessen, D. (2004). Making Sense of Intellectual Capital – Designing a Method for the Valuation of Intangibles, Elsevier, Butterworth-Heinemann, 2004.
[2] Pulic, A. (2000). VAIC – An Accounting Tool for IC Management, International Journal of Technology Management, Volume 20, Issues 5-8, 2000, pp. 702-714.
[3] Gouveia, L.; Couto, P. (2017). A Importância Crescente do Capital Humano, Intelectual, Social e Territorial e a sua Associação ao Conhecimento, Atlântico Business Journal, Volume 1, Number 0, October, 2017, pp. 28-34.
[4] Gouveia, L.; Pinto, P. (2017). Contributo para a Discussão sobre a Contabilização do Conhecimento e do Capital Humano nas Organizações, Atlântico Business Journal, Volume 1, Number 0, October, 2017, pp. 35-37.
[5] Palacios, T.; Galván, R. (2007). Intangible Measurement Guidelines: A Comparative Study in Europe, Journal of Capital Intellectual, Volume 8, Number 2, 2007, pp. 192-204.
[6] Berzkalne, I.; Zelgalve, E. (2014). Intellectual Capital and Company Value, Procedia – Social and Behavioral Sciences, Volume 110, January, 2014, pp. 887-896.
[7] Gogan, L.; Draghici, A. (2013). A Model to Evaluate the Intellectual Capital, Procedia Technology, Volume 9, 2013, pp. 867-875.
[8] Yildiz, S.; Meydan, C.; Güner, M. (2014). Measurement of Intellectual Capital Components Through Activity Reports of Companies, Procedia – Social and Behavioral Sciences, Volume 109, 2014, pp. 614-621.
[9] Sekhar, C.; Patwardhan, M.; Vyas, V. (2015). A Delphi-AHP-TOPSIS Based Framework for the Prioritization of Intellectual Capital Indicators: A SME´s Perspective, Procedia Social and Behavioral Sciences, Volume 189, 2015, pp. 275-284.
[10] Nhon, H.; Phuong, N.; Trung, N.; Thong, B. (2020). Exploring the Mediating Role of Dynamic Capabilities in the Relationship Between Intellectual Capital and Performance of Information and Communications Technology Firms, Cogent Business & Management, Volume 7, Number 1, 2020, pp. 1-18.

[11] Al-Hemyari, Z.; Al-Sarmi, A. (2018). Information Management Model for Intellectual Capital of HEI´s in Oman: Theorethical Quantitative Approach and Practice Results, Journal of Information & Knowledge Management, Volume 17, Number 1, 2018, pp. 1-38.

[12] Tejedo-Romero, F.; Rodrigues, L.; Craig, R. (2017). European Research on Management and Business Economics, Volume 23, Issue 3, 2017, pp. 123-131.

[13] Caputo, F.; Giudice, M.; Russo, F. (2016). Corporate Disclosure and Intellectual Capital: The Light Side of Information Asymmetry, International Journal and Financial Accounting, Volume 8, Number 1, 2016, pp. 1-23.

[14] Ousana, A.; Fátima, A.; Majdi, A. (2011). Usefulness of Intellectual Capital Information: Prepares´ and Users´ Views, Journal of Intellectual Capital, Volume 12, Number 3, 2011, pp. 430-445.

Investment Approach by Alpha Value: Case of Firms Listed on the Stock Market in Vietnam Period Before and After the Covid-19 Pandemic

NGUYEN Anh Phong[a,b, 1], DANG Huyen Linh[a,b], NGUYEN Thi Tra My[a,b], CAO Hoang Nam[a,b], NGUYEN Ha Nam Phuong[a,b], NGUYEN Huynh Phuong Vy[a,b]

[a] *University of Economics and Law, Vietnam*
[b] *Vietnam National University, Ho Chi Minh City, Vietnam*

Abstract. This paper has approached the investment method by alpha value as the excess return to compensate for risks other than the market risk with the data sample of filtered stocks from three major exchanges of the Vietnam stock market HOSE, HNX, and UPCOM from January 2016 to December 2020. Then, we compare the performance of the portfolio through 2021, the year Vietnam fell into the 4th wave of Covid and was the hardest hit. The results of the paper have shown that the portfolio selected by the alpha method has eliminated the beta market risk of the portfolio and has the actual portfolio return higher than the general rate of return of the stock market index, thereby reinforcing and proving the effectiveness of the alpha investment model.

Keywords. Investment method, Alpha value, CAPM, Vietnam stock market, Covid-19 pandemic

1. Introduction

Risk plays a major part in the uncertainty of future cash flow. In general, the risk is the difference between the actual and expected return. The risk could be defined in many different ways depending on each analyst; however, the main purpose of using a risk indicator is to measure the expected return of securities. The modern portfolio theory divides risk into two typical types systematic risk and unsystematic risk. Systematic risk is also known as market risk and is measured by beta which is a gauge of a security's volatility relative to the market's volatility in the capital asset pricing model CAPM, developed by two famous researchers [1], [2].

Besides market risk, there are many other types of risks affecting stock returns that were later discovered by researchers like Ross [3]; Banz [4]; Fama and French [5]; Carhart [6]. Later models when adding risk variables other than market risks such as leverage risk, scale risk, value risk, and liquidity risk, all give a lower model residual variable (ε) than must be satisfied the following. Therefore, it is necessary for additional risk variables other than market risk to be added for a better prediction of return and researchers use alpha value to measure the excess return for other risk factors. In other

words, non-zero alpha indicates that the stock is not fairly valued in the market and it is predicted that the price will rise or fall in the future.

As a result, the alpha coefficient in the CAPM model is crucial in predicting a stock's rate of return, and by looking at the alpha coefficient, investors can determine whether a stock is reasonably priced in the market or not, and thus predict the expected growth of securities in the future to develop appropriate investment strategies. Based on the objective factors mentioned, this study will research and develop "Investment approach by alpha value: case of firms listed on the stock market in Vietnam".

The rest of the paper is organized as follows: section 2 Literature review which reviews and assesses the limitations of the previous studies related to this study, section 3 explains Data and Methodology, section 4 discusses the empirical results and section 5 concludes and recommends investors and the future research.

2. Literature Reviews

Assessing the risk and return of a security is a complex and lengthy research process. One of the widely used models to study the relationship between risk and return on stocks is the Capital Asset Pricing Model (CAPM), developed by two famous researchers Sharpe and Lintner in the 20th century. According to CAPM theory, the return of stocks is evaluated only based on the impact of the market risk - beta coefficient and this is also a major shortcoming of this model. There have been many research papers supporting the effectiveness of the CAPM model's results in predicting stock returns. Besides, the limitations of CAPM was pointed out in several studies when CAPM was only based on market risk to predict stock required returns comparing with other risks or model, including the studies of Basu [7], Rosenberg, Reid and Lansten [8], Bhandari [9], Hasan Kamil, Mustafa and Baten [10], Zainul & Shintabelle Restiyanita [11], Janata [12], Matteo [13] ,Laura & Fahad [14], Lu [15], Offiong [16], Leslaw [17], Rojo-Suárez & Alonso-Conde [18]. The measurement of stock return based on only one risk variable, market risk according to CAPM, is not correct and not enough basis.

The researchers then began to search for new risk variables to add to the original CAPM in order to test how the residual error of the CAPM ($\boldsymbol{\varepsilon}$) changes in the case before and after adding the risk variables other than the market risk - beta coefficient. In 1993, Fama and French introduced a three-factor model including market risk and proposed two risk variables other than market risk, namely size risk, and value risk. Carhart then also developed a four-factor model based on the three-factor model of Fama & French and added a momentum factor to assess the influence of these risk variables on stock returns. A perfect model CAPM must be satisfied the following test conditions: the alpha coefficient α which represents a risk premium other than market risk and the model residual, $\boldsymbol{\varepsilon}$, must be zero. In other words, if alpha is non-zero and the residual in the CAPM is greater than zero, it could be seen that there are other risks other than the market risk that affect portfolio returns. The larger the model residual ($\boldsymbol{\varepsilon}$) is, the more error the model has. This leads to the model being less reliable. The previous research results indicated that most of the newly added risk factors in addition to market risk are statistically significant in explaining the required rate of returns. Furthermore, this new model exhibits lower variance (i.e., model residuals) than the capital asset pricing model CAPM, indicating that the later models better quantify the connection between return and risk than the CAPM model. It could be concluded that the required rate of return is also affected by risks other than market risks, such as size risk, value risk, liquidity risk,

and leverage risk. Therefore, the premium for market risk can not be able to compensate for risks other than market risk. To compensate for risks other than market risk, it is necessary to have an additional return for investors which is expressed by alpha coefficient α, which means stocks with positive and statistically significant alpha coefficients will become attractive to investors. Beta coefficients, , that measure market risk are also no longer effective for calculating returns because there are stocks that are not affected by market risk but are affected by other risk factors. In fact, investors do not pay attention to how many risks they may get or what those risks are, what investors care about is how much they get in return on the total risk they take, whose alpha is the compensation for the risks that investors have to take in addition to the market risk. It could be seen that, besides market risk, the required rate of returns is also affected by risks other than market risk, and choosing stocks with positive alpha values to counter risks other than market risk is a legitimate and highly relevant investment strategy. Thus, this paper will demonstrate the investment method according to the alpha approach, and collect the latest information and data. Simultaneously, this paper will be the material to contribute to further studies on alpha investment and evaluate the risk and return of securities in the future.

3. Data and Methodology

3.1 Data

The paper aims to build a portfolio according to alpha value, which is a long-term buy-and-hold method. Therefore, instead of daily or weekly data, we chose to collect data on a monthly basis from Thomson Reuters, and Refinitiv and ignore short-term price movements. Accordingly, data are collected for 5 years from January 2016 to December 2020 to compute the monthly return of market indexes and individual stocks listed on Vietnam's stock exchange. Initially, the collected data is 1,655 stocks listed on the whole Vietnam stock market. The selected stocks must ensure full trading conditions and not change the exchange during the 5-year listing period. However, there are some limitations to this paper. In terms of risk-free interest rate data, we chose a 10-year Vietnamese government bond. According to Fitch Ratings [19], Vietnamese government bonds are rated BB by regional and international organizations in terms of creditworthiness. In essence, the BB rating indicates that Vietnamese government bonds are not completely risk-free. However, in terms of the Vietnamese market alone, government bonds are the safest asset, and Vietnamese government bond yields can represent the risk-free rate of the study.

3.2 Methodology

With the alpha investment method, the research team uses the CAPM model Eq. (1) to perform linear regression in Excel, in order to find stocks with statistically significant positive alpha, the linear regression equation has the formula as follows:

$$CAPM: (Ri - Rf) = \alpha + \beta(Rm - Rf) + \varepsilon \qquad (1)$$

where:
Dependent variable (Ri - Rf): individual security risk premium

Independent variable (Rm - Rf): market risk premium

α: intercept coefficient (represents alpha)

β: is the coefficient that measures the variation of stock risk premium with the market risk premium

ε: model residuals

Since the Vietnamese stock market has three separate exchanges, the collected data set is performed linearly according to the CAPM formula on each individual stock of 3 exchanges HOSE, HNX, UPCOM corresponding to the return of three different markets (Rm) are VN–INDEX, HNX-INDEX, and UPCOM-INDEX. After performing linear regression on Excel for all stocks listed on the Vietnam stock market and meeting the set criteria, a set of stocks with positive alpha with statistical significance was selected. In this set of data, continue to find stocks with positive and negative beta that are statistically significant to combine into an alpha portfolio. A Solver algorithm is used to determine the proportion of capital allocation of stocks in the portfolio according to alpha in order to minimize the market risk of the portfolio (Portfolio beta = 0). Markowitz's efficient portfolio capital allocation theory is applied to construct the optimal portfolio in terms of alpha of this study. After building an alpha portfolio from Excel's Solver algorithm, the paper studies the practical application of the alpha portfolio in 2021, thereby measuring the actual return of the portfolio using the alpha method in 2021 and comparing it with the stock market index VNINDEX 2021. The study also compares the return forecast of the alpha investment method with the CANSLIM method, thereby proving the effectiveness of the alpha investment method.

4. Result and finding

After performing linear regressions according to the CAPM model on a total of 784 eligible stocks listed on the Vietnam stock market, the results show that there are 6 stocks with statistically significant positive alpha. However, there is only one stock - ABI, that carries both a statistically significant positive alpha and a statistically significant beta. That is an ABI stock with alpha value equal to 0.04095, and an alpha p-value of 0.00042; ABI also has a positive beta and a beta p-value of 0.01283, showing that ABI stock meets the alpha and beta requirements with statistical significance. Since there is only one stock (ABI) that meets the alpha and beta conditions to be statistically significant, the initial objective of finding a portfolio of statistically significant positive alpha and positive/negative beta stocks is not possible. Therefore, the research team decided to proceed with the construction of two portfolios in the following ways:

- The first portfolio is the combination of stock ABI - statistically significant positive alpha and positive beta, with four stocks carrying statistically significant negative beta, alpha has no statistical significance.
- The second portfolio is a combination of all 6 statistically significant positive alpha stocks with statistically significant positive/negative beta stocks but no significant alpha.

In order to construct the Markowitz portfolio optimization, the Solver algorithm on Excel was used with the following conditions: portfolio annual standard deviation is less than or equal to 20%, portfolio beta equal to zero, total capital disbursement to the portfolio is 100%.

However, the results of capital allocation according to Solver to the second portfolio include only 6 stocks with statistically significant positive alpha. Stocks with statistically significant positive and negative beta have no weight in the portfolio. Therefore, the second portfolio is excluded because it does not satisfy the market risk minimization condition (beta = 0), as the betas of the stocks in the portfolio are not statistically significant. Otherwise, the capital allocation result of stocks in the first investment projects is shown as follows:

Table 1. Solver results of capital allocation to the first optimal portfolio

Weights of Stocks		Stock Beta	Weighted Beta
ABI	43.51%	0.55	0.24
ALT	26.56%	-0.33	-0.09
L18	27.33%	-0.45	-0.12
CT3	2.60%	-1.02	-0.03
Total weights	**100.00%**	**Portfolio Beta**	**0.00**

Source: Authors' analysis

Solver results of capital allocation to the first portfolio show that the individual positive beta stock has offset the negative beta stock. Hence, the portfolio has a beta equal to zero, indicating that the portfolio has minimized market risk. Accordingly, this alpha-based investment is expected to yield an annual return of 26.68% with a standard deviation (or risk) of 20.17%/year. Additionally, this portfolio has a Sharpe ratio of 1.0652 based on the risk-free rate of 5.19% annually.

Therefore, only the first optimal portfolio is selected for simulation with the empirical return in 2021 (We compare the portfolio performance through 2021, which is the year Vietnam fell into the 4th wave of the Covid epidemic and was hardest hit), and the actual return on the investment portfolio alpha in 2021 is shown as follows:

Table 2. Actual profitability of the first optimal portfolio

Stock Symbol	Stock Exchange	Name	Closing price at the end of 2020	Closing price at the end of 2021	Gain/ Loss (Ri)	Portfolio weights (Wi)	Proportional rate of return (Ri*Wi)
ABI	UPCom	Agriculture Bank Insurance JSC	86.6%	375	294	78.4%	414
ALT	HNX	Tan Binh Culture JSC	80.5%	384	294	76.6%	694
CT3	UPCom	Project 3 Construction & Investment JSC	74.3%	376	294	78.2%	804
L18	HNX	Investment & Construction JSC No.18	73.3%	367	294	80.1%	872
Actual rate of return of the first optimal portfolio: $R_P = \sum_{i=1}^{n} w_i r_i$							**215.86%**
VNINDEX (Benchmark)			1103.87	1498.28	+/- %		**35.7%**

Source: Authors' analysis

The empirical comparison shows that the first optimal portfolio offers superior performance compared to the VN-INDEX as a benchmark, which is 180.16% higher than the market return (VN-INDEX). Alpha investing is a long-term buying and holding method in search of a yield that outperforms the general market. However, the actual return in 2021 of the alpha-based investment portfolio shows that this is a highly effective investment method, yielding 6 times the return compared to the market return within just one year.

In addition, to verify the effectiveness of the alpha investment method, the research team also built an investment portfolio based on the CANSLIM stock selection method to compare the performance with the alpha investment portfolio. CANSLIM method *("C" - Current quarterly earnings per share; "A"- Annual earnings increases; "N" - New Products, New Management, New Highs; "S" - Supply and Demand; " L" - Leader of Laggard; "I" - Institutional Sponsorship; "M" - Market Direction)* which is the well-known stock selection method developed by William J. O'Neil. Screening stocks on the Vietnam stock market according to some criteria of the CANSLIM stock selection method, the results show that there are 3 stocks that meet the above criteria: DGC (HOSE), VND (HOSE), ORS (HOSE). The Solver algorithm in Excel was used to find the portfolio weights with the following conditions: portfolio annual return is 26.68% (equal to the annual return of the alpha-based portfolio), minimizing the standard deviation of the portfolio, portfolio beta equal to zero, total capital disbursement to the portfolio is 100%; the results of the investment portfolio according to CANSLIM include the proportions of stocks as shown in the table below:

Table 3. Solver results of capital allocation to the portfolio according to CANSLIM

Weights of Stocks		Stock Beta	Weighted Beta
DGC	53.57%	0.84	0.45
ORS	18.01%	1.04	0.19
VND	28.42%	1.28	0.36
Total weights	**100.00%**	**Portfolio Beta**	**1.00**

Source: Authors' analysis

Comparing the actual profitability in 2021 shows that the investment by CANSLIM gives a higher return of 62.41% than the one by alpha (278.27% > 215.86%). However, alpha-based investment is more efficient due to its higher Sharpe ratio, the figures are 1.0652 and 0.8015 respectively. In other words, the ratio between return and risk of the former and the latter are 1/0.939 and 1/1,248 respectively, that is, for one additional unit of profit applied to both investment portfolios, investors following the alpha-based portfolio only incur an additional 0.938 units of risk, while the CANSLIM-based portfolio incurs an additional 1,247 units of risk.

Table 4. Comparison of the indicators of the alpha-based portfolio and the CANSLIM-based portfolio

	Annual rate of return	Annual standard deviation	Sharpe ratio	One unit of profit/ risk
Alpha-based portfolio	215.86%	20.17%	1.0652	1/0.939
CANSLIM-based portfolio	278.27%	31.52%	0.8015	1/1.248

Source: Authors' analysis

5. Conclusion and recommendation

A special feature of the topic is that the study expands and suggests a new investment method for investors, which is the method of investment according to quantitative models. The investment model proposed by the authors is an alpha investment model, giving quite acceptable and superior results of assessing the relationship between stock risk and return even when compared with the stock market index VNINDEX and the CANSLIM stock selection method model. From the research results presented in section 4, it can be concluded that the investment portfolio proposed by the authors based on the alpha investment method is suitable, brings outstanding returns and applies in Vietnam's

stock market. However, due to the volatile and illiquid nature of the selected stocks in the portfolio, the research results are only really useful for investors who have long-term investment purposes. In other words, investors tend to buy and hold securities investment strategies.

References

[1] Lintner, J. (1965). Security prices, risk, and maximal gains from diversification. The journal of finance, 20(4), 587-615.

[2] Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. The journal of finance, 19(3), 425-442.

[3] Ross, A. S. (1976). The arbitrage theory of capital asset pricing. Journal of Economic Theory, 13(3), 341-360. https://doi.org/10.1016/0022-0531(76)90046-6.

[4] Banz, R.W. (1981). The Relationship between Return and Market Value of Common Stocks. Journal of Financial Economics, 9(1), 3-18. http://dx.doi.org/10.1016/0304-405X(81)90018-0.

[5] Fama, E. F., & French, K. R. (1995). Size and book‐to‐market factors in earnings and returns. The journal of finance, 50(1), 131-155.

[6] Carhart, M. M. (1997). On persistence in mutual fund performance. The Journal of finance, 52(1), 57-82.

[7] Basu, S. (1983). The relationship between earning yield, market and return for NYSE common stocks: Further evidence. Journal of financial economics, 12(1), 129-156.

[8] Rosenberg, B., Reid, K. and Lanstein, R. (1985) Persuasive Evidence of Market Inefficiency. Journal of Portfolio Management, 11(3), 9-17

[9] Bhandari, L. C. (1988). Debt/equity ratio and expected common stock returns: Empirical evidence. The journal of finance, 43(2), 507-528.

[10] Hasan, Z., Kamil, A. A., Mustafa, A., & Baten, A. (2013). Analyzing and estimating portfolio performance on theBangladesh stock market. American Journal of Applied Sciences, 10(2), 139-146.

[11] Zainul, K., & Shintabelle. R. M (2015). The Validity of Capital Asset Pricing Model (CAPM) and Arbitrage Pricing Theory (APT) in Predicting the Return of Stocks in Indonesia Stock Exchange 2008 - 2010. American Journal of Economics, Finance and Management, 1(3), 184-189. http://www.aiscience.org/jornal/ajefm

[12] Janata, G. (2016). Validity of the capital asset pricing model (CAPM) for securities trading at the Nairobi SecuritiesExchange (NSE). Business and Management Research, 5(4). doi.org/10.5430/bmr.v5n4p62.

[13] Matteo, R (2016). The capital asset pricing model: a critical literature review. Global Business and Economics Review, 18(5), 604-614.

[14] Laura, M. R., & Fahad, N. U. (2017). The classical approaches to testing the unconditional CAPM: UK evidence. International Journal of Economics and Finance, 9(3), 220-232.

[15] Lu, Z. (2017). The investment CAPM. National BUREAU OF Economic Research. doi.10.3386/w23226.

[16] Offiong, A. I., Riman, H. B., & Mboto, H. W. (2020). Capital Asset Pricing Model (CAPM) and the Douala Stock Exchange. International Journal of Financial Research, 11(5). doi:10.5430/ijfr.v11n5p191.

[17] Leslaw, M. (2020). Further evidence on the validity of CAPM: The Warsaw stock exchange application. Journal of Economics & Management, 39, 82-104

[18] Rojo-Suárez, J., & Alonso-Conde, A. B. (2020). Consumer sentiment and time-varying betas: Testing the validity of the consumption CAPM on the Johannesburg Stock Exchange. Investment Analysts Journal, 49(4), 303-321.

[19] Fitchratings.com. 2022. Vietnam. [online] Available at: <https://www.fitchratings.com/entity/vietnam-80442269> [Accessed 9 April 2022].

Multivariate Research on Satisfaction Influencing Factors of Flipped Classroom Teaching Mode

Jie HE[1], Tingjuan MA, Yongliang ZHANG, Lin CHEN and Yajuan ZHANG
Baoji Vocational & Technical College, Baoji 721013, China

Abstract. Based on the theory of Technology Acceptance Model (TAM) and American Customer Satisfaction Scale (ACSL), this study selects 130 students majoring in preschool education, Chinese education and primary education in a higher vocational college in China as the research sample from the perspective of technology and consumers to carry out college English flipped classroom teaching based on SPOC (Small Private Online Course) mobile interactive learning platform. Through descriptive statistical analysis, factor regression analysis and the influence mechanism of common factors, this study aims to investigate and analyze students' satisfaction of flipped classroom on 30 items. The results show that learners' satisfaction cognition of flipped classroom is deeply influenced by three common factors: Learners' expectation, cognitive quality and learning acceptance. Furthermore, the findings indicate that high quality activity design is the key factor for the success of flipped classroom, learners' expectation of flipped activities is the internal driving force, and learners' acceptance of flipped classroom teaching mode is the main factor.

Keywords. Flipped Classroom, Satisfaction, Acceptance, College English, SPOC, Influence Factor

1. Introduction

With the rapid development of cloud computing, big data, Internet of things, AI, 5G and other modern information technologies, Internet plus education has become a new normal for future education development. "The Outline of the National Medium- and Long-term Education Reform and Development Plan (2010-2020)"[1] points out that it is necessary to take reform and innovation as a strong driving force for education development and improve quality as the core task of education and teaching reform and development. To develop education, we should fundamentally rely on reform and reform the teaching contents, modes, methods and means. "The Ten-Year Development Plan for Educational Informatization (2011-2020)" issued by the Ministry of education in 2012

---

[1] Corresponding Author, Jie HE, Baoji Vocational & Technical College, Baoji 721013, China; Email: jesson1227@126.com.

further emphasizes the necessity to give full play to the unique advantages of modern information technologies and explore the establishment of a new learner centered teaching model. It is particularly vital to encourage students to use information means to study actively, independently and cooperatively, cultivate students' good habits of using information technologies, develop their interests and specialties, and improve the quality of learning.

In recent years, flipped classroom is triggering a new wave of educational model reform, and has become one of the focus topics in the field of higher education and educational theory [2]. American online education media e-campus news network listed flipped classroom as one of the top ten educational technology events in 2011 and Professor Daphne Koller of Stanford University believes that the new form of teaching supported by flipped classroom technology may be a major change after the classroom teaching mode since the European Renaissance [3]. Furthermore, flipped classroom was rated as a major technological change affecting classroom teaching in 2011 by the global mail of Canada [4].

In China, some universities and scientific research institutions have also implemented the research on the localization of flipped classroom teaching mode and the practical exploration of flipped classroom teaching process, evaluation mechanism, teaching strategy and activity design. However, there is still a lack of empirical research on learner satisfaction survey and evaluation and impact factor analysis in China. The factor analysis of satisfaction is an important reference index for learners' formative evaluation. In terms of College English education, formative assessment based on satisfaction factor analysis helps students acquire language knowledge, improve language skills and achieve the goal of in-depth learning. It not only has the function of diagnosis promotion, feedback and incentive, but also has the function of reflection and summary [5]. This study takes college English teaching as an example, chooses SPOC mobile interactive platform as the research platform, designs a questionnaire based on TAM and ACSI, and implements relevant statistical analysis and empirical research, which not only provides theoretical and data reference for the implementation of flipped classroom in the field of Higher Vocational Education in China, but also expands the research direction of flipped classroom.

2. Literature Review

With the gradual deepening and wide application of flipped classroom teaching practice, the research related to flipped classroom is also increasing, and a series of research results have been produced. These achievements involve different disciplines such as economics, mathematics and mechanical engineering, and the subjects are mainly natural and engineering disciplines, while humanities and social sciences are relatively few. Their main topics focus on the teaching design and implementation strategy of flipped classroom, the concept, connotation and main characteristics of flipped classroom, and the comparative research between flipped classroom and traditional classroom. After years of flipped classroom teaching practice, the founders Jonathan Bergmann and Aaron Sams published a monograph, summarized the relevant theories of flipped classroom and shared their research and practical experience. Marco Ronchetti [6] focuses on exploring the methods, strategies and effects of online video instead of traditional teaching practice. Jeremy F. Strayer [7], an American educational technology expert, confirmed that flipped classroom has a significant positive impact on the cultivation of learners'

collaborative ability and innovative ability through a comparative study with traditional classroom. Moreover, Lage and Platt of the University of Miami introduced in detail their ideas, methods and effects of applying and implementing flipped classroom in microeconomics course [8]. After years of flipped classroom teaching experiments, Professor Robert Talbert of Franklin college in the United States summarized the public recognized flipped classroom implementation structure model of two stages in pre class and in class [9] (See Figure 1.)
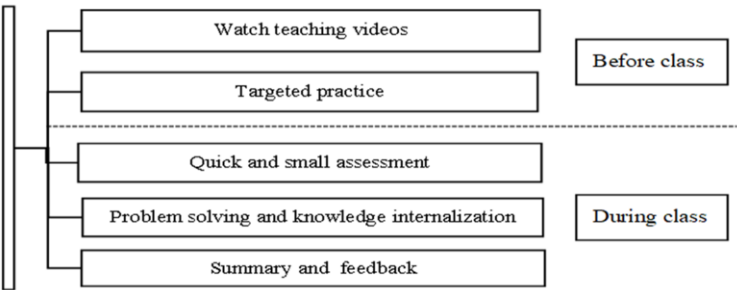
Figure 1. Robert Talbert flipped classroom implementation structure diagram

Although the research on flipped classroom in China started late, it has gradually attracted the attention of higher education circles and become one of the research hotspots. It is mainly reflected in the flipped classroom teaching mode, strategy, evaluation, effect and other aspects. Based on the analysis of the connotation and advantages of flipped classroom teaching mode, Xue and Zheng constructed a SPOC flipped classroom teaching mode with three platforms, three stages, three steps and three links and elaborated on the specific content of the model with three stages as the main line. Then, based on the model, the practice of flipped classroom of computer basic courses is carried out. on the basis of the analysis of the difficulties faced by college English teaching in the information age [10], Dou and Wen put forward a college English flipped classroom teaching model based on e-learning platform [11]. The research shows that this model has more advantages than the traditional classroom teaching model in stimulating students' interest in learning, enhancing the communication and interaction between instructors and students and deepening knowledge understanding. Lv and Wang explore the college English classroom teaching model based on SPOC + digital teaching resource platform by using the methods of comparative experiment, quantitative analysis, questionnaire survey and instructor-student interview, the result of which shows that the teaching experiment plays a positive role in improving learners' comprehensive English application ability and learning efficiency, avoids a lot of repetitive work of instructors, and is conducive to the implementation of innovative teaching [12]. Guided by the concept of flipped classroom, Zhang and Tao attempt to create some "flipped" elements in the SPOC teaching environment by taking advantage of high-quality network resources and some advantages of traditional classroom teaching.

Furthermore, With the help of a variety of learning platforms and mobile learning tools, many other researchers such as [13],[14],[15],[16],[17],[18],[19],[20],[21], [22],[23],[24] explore and build a flipped classroom teaching model suitable for different subject teaching and different learners' learning. These studies also show the advantages of flipped classroom teaching model from different dimensions. For instance, these models can effectively improve the quality of classroom teaching, cultivate learners' autonomous learning ability, improve metacognitive level, reduce cognitive load,

improve subject learning performance, enhance learners' satisfaction with the course and so forth.

Macroscopically, Zhang and Meng analyzed and demonstrated the value, limit and symbiosis of learning guidance case teaching and flipped classroom teaching [25]. Zhang analyzed the key factors such as the design of teaching video, the construction of personalized collaborative learning environment and the design of classroom activities [26]. Flipped classroom is an effective way to promote the deep integration of information technology and education [27]. Wang and Wu pointed out that under the flipped classroom mode, students' subjective norms and subjective attitudes directly affect their learning behavior [28]. Learning tasks, learning environment, learning evaluation and teaching management have a significant positive impact on students' subjective norms. Video learning resources, teaching activity design and instructors' classroom teaching have a significant positive impact on students' subjective attitudes and information technology support is no longer the main factor affecting students' learning behavior in flipped classroom. Zhu and Zhu; Wei; Huang and Zheng; and Gao discussed and explicated the strategies for the effective implementation of flipped classroom, including establishing new teaching ideas, constantly improving the ability to implement flipped classroom, focusing on cultivating students' learning skills, changing instructors' roles, making high-quality pre-class videos, and carrying out various forms of classroom activities [29][30][31][32]. Moreover, Liu et al. conducted systematic evaluation and meta-analysis on the effectiveness of SPOC flipped classroom teaching [33]. The results showed that the examination scores, knowledge understanding ability, knowledge application ability, self-study ability, self-management ability and learning motivation of SPOC flipped classroom are higher than those of traditional classroom.

Through the literature review of existing domestic research, we find that the researches on flipped classroom in China are still lack of researches on the whole and mutual influence relationship, and the lack of comparative researches between domestic and foreign countries, which limits the exploration of flipped classroom in higher education in China in the analysis of influencing factors. Based on the theory and empirical researches of flipped classroom at home and abroad, this study designs the satisfaction questionnaire of flipped classroom in college English in China, and seeks its influencing factors, so as to provide theoretical basis and practical support for building a flipped classroom model suitable for college English teaching environment in China.

3. Implication of SPOC

SPOC (small private online course) is a small-scale private online course formed by setting participation access conditions (mainly for school students), which is mainly composed of micro videos, real-time online practice, online interactive discussions, various tests and other elements. Essentially, it is a blended learning mode of MOOC localization, which overcomes the problem that MOOC cannot match the teaching objects, curriculum objectives, difficulties and students' existing knowledge accumulation of existing courses [34]. It has the characteristics of directivity, limitation, flexibility, goal orientation and so on. Its importance is that online learning has jumped out of the stage of copying classroom courses, and is trying to create some more flexible and effective ways to enhance instructors' guiding role and students' mastery of knowledge and participation [35][36].

4. Definition of Flipped Classroom

Researchers at home and abroad have different entry points in defining the concept of the flipped classroom. The concept of flipped classroom was first put forward by two instructors of Woodland Park High School in Colorado. Its basic idea is to turn the traditional learning process upside down, so that learners can complete independent learning for knowledge points and concepts in extracurricular time, and the classroom becomes a place for interaction between instructors and students, which is mainly used to answer doubts, report and discuss, so as to achieve better teaching results [37]. Flipped classroom refers to a new teaching mode that changes the roles of instructors and students in traditional teaching and re plans the use of classroom time through the reversal of knowledge transfer and knowledge internalization. It changes the traditional "teaching centered" and adopts "student-centered" personalized teaching [38]. Brian Gonzalez, Intel's director of global education, points out that the emergence of the flipped classrooms is an example of exploring learner' learning space, which provides learners with a freer learning space. He argues that knowledge learning in the flipped classroom takes place outside the classroom, and learners can learn new knowledge according to their own learning habits and methods, and improve their learning ability. As a matter of fact, Brian points out the differences between the traditional classroom and the flipped classroom in the process of teaching implementation and learners' learning experience. Zhong, song and Jiao argue that the so-called flipped classroom is that instructors raise questions in an information-based environment and instructors and students can complete the teaching and learning activities in the form of video, inquiry and other interactive teaching resources for learners [39].

Furthermore, Jin is the first place to define the flipped classroom in China. He claims that the flipped classroom means turning over the traditional teaching mode that instructors teach in the classroom during the day and learners go home at night to do homework, and constructing learners to absorb and internalize knowledge in the classroom during the day, and to complete the learning of new knowledge after class [40]. Zhong who is working in the Information Technology Center of Tsinghua University and other researchers claim that the so-called flipped classroom is a kind of teaching and learning activity mode in which instructors provide learners with teaching videos and carry out teaching activities in the context of information technology, learners watch and learn these videos and other learning resources before class, and then instructors and learners complete homework answering, collaborative inquiry and interactive communication together in the classroom [41]. It can be seen that experts and scholars at home and abroad have different definitions of the flipped classroom according to their own understanding and explanation, but generally speaking, the flipped classroom should include at least four aspects: the development and production of curriculum video, self-study and mutual learning before class, classroom absorption and internalization, and summary of report and discussion. After summarizing the theoretical definition of the flipped classroom, we believe that the flipped classroom is a brand-new teaching mode based on network information technology. That is to say, instructors provide micro courses and other related learning resources for students to study autonomously or explore knowledge cooperatively before class. Students in class report and perform what they have learned or discuss and solve problems that cannot be solved with the help of instructors so as to further absorb and internalize the knowledge learned [42].

5. Construction of Flipped Classroom Teaching Mode Based on SPOC

5.1. Prototype Teaching Mode Based on SPOC

During 2009-2012, students' homework for holiday in Changle No.1 Middle School couldn't be checked timely by instructors. Aiming at this problem, the school carried out such a series of network learning mode as the QQ group holiday work instruction, the network learning platform for autonomous learning, teaching micro video explanations and so on. What's more, they introduced this network learning mode to teaching practices. Thus, the embryonic form of flipped classroom came into being. In October 2013, Changle No.1 Middle School put forward their specific flipped classroom teaching mode which is called "Two-stage, Four-step and Ten-segment".

The "Two-stage" means the self-study and questioning stage and practice and presentation stage. The "Four-step" means class hour planning, micro class production, case design and micro class recording. "Ten-segment" includes target setting, autonomous learning, watching micro classes, interactive learning, online learning, difficulty solving, practice, presentation, cooperative improvement and evaluation feedback [43].

On the basis of the flipped classroom mode of Changle No.1 middle school, this research effectively takes advantage of SPOC mobile interactive learning platform to implement the design of integrated learning activities, realize the organic integration of various learning activities, and then achieve the goal of in-depth learning. This teaching mode is more conducive to cultivating students' autonomous learning ability and cooperative inquiry ability, and shaping students' critical, creative and speculative thinking. Based on the classic flipped classroom teaching mode at home and abroad and combined with the teaching practice, this paper constructs a blended flipped classroom teaching mode integrating knowledge extraction and micro class production before class, report display and evaluation feedback during class, and consolidation, improvement, adjustment and correction after class. (See Figure 2.).
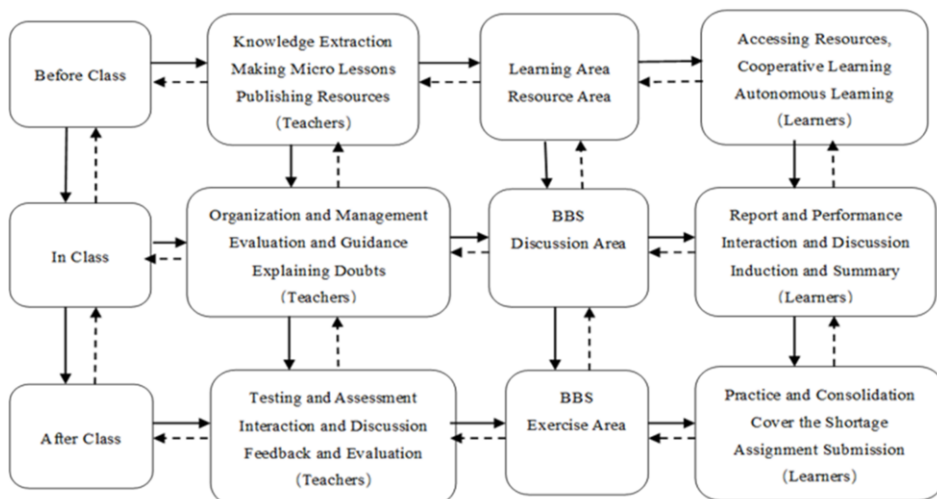

Figure 2. College English flipped classroom teaching model based on SPOC

5.1.1. Knowledge Extraction and Micro-class Production Stage before Class

During this stage, the core task of instructors is to design the teaching content as a whole, to determine the teaching objectives of each part of the teaching content, to screen out the knowledge points that need to be mastered and the difficulties that need to be solved urgently, to put forward the inspiration and guidance issues that drive the teaching, and to design online learning tasks and closed exercises. Based on this, instructors need to write a detailed micro-course design idea, list micro-course production framework and procedures, collect relevant teaching resources and materials, use relevant software to produce high-quality micro-course videos, and publish it to the SPOC learning sharing platform based on Superstar Learning, and inform learners through the platform notification function.

5.1.2. Autonomous Learning and Collaborative Inquiry Stage before Class

After receiving the learning instructions and assignments from instructors through the platform notification release window, learners use mobile phones to enter the learning area anytime and anywhere for pre-class learning according to their learning habits, learning methods and time arrangement, complete the initial absorption and internalization of knowledge, and test their understanding and mastery of knowledge in the ability testing area. In this process, if learners encounter deviations in understanding or problems that are difficult to solve in learning, they can always consult instructors and classmates through the platform chat window, or go to the discussion area for an interactive discussion between instructors and learners and among learners. Finally, learners can complete further absorption and internalization of knowledge through autonomous or collaborative inquiry. Sure enough, to ensure the quality and smooth progress of the learning task in this stage, it is imperative for instructors to timely and efficiently supervise, manage and instruct the learning process of learners.

5.1.3. Report, Presentation, Evaluation and Feedback Stage during Class

After autonomous and collaborative inquiry before class, learners completed the initial absorption and internalization of knowledge and construction, with learning results and learning doubts came to the classroom to report and present or seek the help of instructors. The performance of learners' classroom reports can be presented in groups, situational dialogues, role-play, keynote speeches, drama performances, debates and other forms according to the learning content, in the process of which instructors should play a good role as organizers, controllers and evaluators of activities, inspire and guide learners to summarize learning activities, and further promote learners' absorption and internalization of knowledge.

5.1.4. Consolidation, Improvement, Adjustment and Correction Stage after Class

After two stages of pre-class autonomous and collaborative inquiry and in-class presentation, learners' learning of relevant knowledge has changed from the understanding level to the application level, and the absorption and internalization of knowledge has been completed as well. The main task of this stage is to further strengthen and consolidate the absorption and internalization of knowledge and to systematize knowledge, at which instructors design and compile knowledge and competence test questions and assignments, and provide them to learners through the SPOC teaching platform (See Figure 2).

6. Experimental Design

6.1. Experimental Purpose

Based on the International Technology Acceptance Mode (TAM) and the American Consumer Satisfaction Scale (ACSI), the study designs a questionnaire on the satisfaction of the flipped classroom teaching mode, which combines the domestic and foreign literatures on the flipped classroom teaching mode, and takes full account of the current situation and objective facts of English learning of higher vocational learners. This paper explores the reliability, validity and correlation of each measurement variable through factor analysis with relevant software, and provides theoretical and practical data support for college English teaching in higher vocational colleges. In addition, the study mainly chooses information publishing and mobile learning platform which is suitable for college English flipped classroom teaching in higher vocational colleges in China as an experimental platform.

6.2. Experimental Methods

Considering the high expectation of learners in the technical level and subjective initiative of flipped classroom teaching mode, the design dimension and project setting of the questionnaire are mainly based on the theoretical mode, the existing scale, the relevant important literatures and the practical aspects of higher vocational teaching. In terms of theoretical model, at present, most of the research on learner satisfaction in the field of higher education is revised based on ACSI, and more online education also widely draws lessons from TAM model. This study compares the two models and refines the observation variables of teaching quality in ACSI. In terms of scale, because the performance evaluation of flipped classroom in foreign language teaching is a dynamic process, special attention is paid to the improvement of learners' learning initiative and consciousness and the establishment and maintenance of teaching environment. In teaching evaluation, it is natural to pay more attention to formative evaluation and weaken summative evaluation. Therefore, this study focuses on online learning certification standard scale. In terms of references, since there is no research on the influencing factors of satisfaction of flipped classroom teaching model and the construction of theoretical model in China, this study refers to the research results of Jeremy F. Strayer and other foreign scholars. Based on this, the research team selected learner expectation, learner acceptance and learner satisfaction as observation variables, among which learner acceptance includes five dimensions:

- Operability and practicability of SPOC teaching platform.

- Usability and effectiveness of online courses.

- Interaction of face-to-face class.

The questionnaire in the study includes two parts: the main part of the questionnaire and the description of personal information. The main part is composed of 35 questions designed from different perspectives of the flipped classroom teaching mode. In order to ensure the reliability and validity of the questionnaire, a reverse item is added to each question. The survey scale is indicated from 1 to 5, which means totally disagree,

disagree, neutral, agree and fully agree respectively, and all the statistical data are analyzed by SPSS22.0 analysis software.

6.3 Experimental Participants

The participants of the study are 130 students majoring in pre-school education, Chinese education and primary school education in the first year of Baoji Vocational and Technical College, all the participants were admitted through the National College Entrance Examination, 120 of whom are girls and 10 of whom are boys aged between 18 and 20 years old because the students studying education in China are almost girls, and the teaching materials were selected from the New Horizon English Reading and Writing Course (Third Edition), edited by professor Zheng Shu-tang. All participants in the experiment accepted a one-year flipped classroom teaching practice, including 72 hours of online course learning tasks. After the experiment, a questionnaire survey was conducted among the participants. The research team sent out 130 questionnaires and received 125 questionnaires. After screening, 5 invalid questionnaires were removed. The actual valid questionnaires are 120 and the validity rate of the questionnaires is 96%.

7. Discussion and Analysis of Research Results

7.1. Validity Analysis

The principal component method in statistical analysis is used to analyze and measure the collected data, which can test the validity of the collected data well. Meanwhile, the relationship between statistical variables can be observed effectively. We use factor analysis to analyze the questionnaire data, and use KMO and Bartlett test to sample the data according to the eigenvalue greater than 1. According to KMO statistical standard, when KMO > 0.9, factor analysis can be carried out ideally. We randomly selected 30 questions from 35 questions and selected 7 factors for KMO test. The test value was .804, which indicated that the correlation between the observed variables was not very different. In addition, the approximate Chi-square Value of Bartlett Sphere Test is 1543.754, and the Sig. is 0.002, which is less than the minimum requirement of 0.05. It can be seen that the zero hypothesis of Bartlett Sphere Test is not valid and the values of each variable are correlated. Therefore, the sample is more suitable for factor analysis (See Table 1).

Table 1. KMO and Bartlett Test Statistics

Kaiser-Meyer-Olkin Measure		. 804
Bartlet Sphere Test	Approximate Chi-square Value	1543.754
	df	356
	Sig.	. 002

7.2. Reliability Test

For the purpose of testing learners' satisfaction with the flipped classroom teaching mode, reliability analysis of the factors involved in the question is needed. Cronbach's Alpha coefficient is a commonly used method for reliability test, which is generally believed that when a > 0.6, the reliability of statistical analysis data is higher. The overall alpha reliability coefficient of the questionnaire is 0.85, which indicates that the reliability of the questionnaire is very high. The results of reliability analysis show that Cronbach's Alpha coefficient are between 0.65 and 0.761, which fully shows that the questionnaire items have high reliability and the consistency among the factors is good. In the meantime, it also shows that the three common factors selected in the study can better measure learners' satisfaction with the college English flipped classroom teaching mode (See Table 2).

Table 2. Reliability Analysis Statistics

Item		Cronbach's Alpha
Learner Expectation		.745
Acceptance Dimension	Operability of Learning Platform	.761
	Practicality of Learning Platform	.760
	Usability of Online Courses	.758
	Practicality of Online Classroom	.756
	Interaction in Face-to-face Class	.650
Learner Satisfaction		.759
Overall Reliability of the Project		.850

7.3. Regression Factor Analysis

In order to observe the satisfaction of each factor to the teaching of the flipped classroom teaching mode and provide a powerful data reference for future teaching reform, we selected three common factors as independent variables to continue to observe the overall satisfaction of the flipped classroom teaching mode as dependent variables, and made a regression equation analysis. It can be seen from the scatter plot (See Figure 3.) that the standardized residuals mainly fall between (-2, 2), which indicates that the learners' overall satisfaction with the teaching mode of College English flipped classroom in higher vocational colleges is higher and the fitting degree is better.
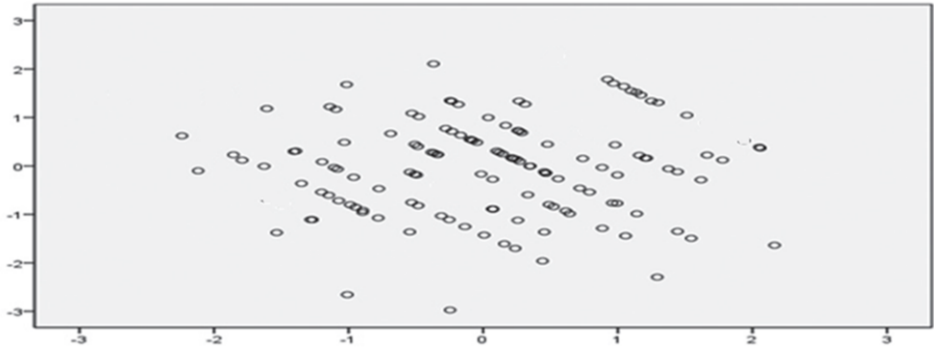
Figure 3. Scatter Plot of Regression Equation Analysis

The research team conducted T-test analysis on learner expectation, learner acceptance and learner satisfaction. The values of Sig. are .041, .045 and .034 respectively have significant differences (See Table 3). It is clear that the basic relationship based on SPOC among the above three variables can be seen, which also shows that learners' expectation, acceptance and satisfaction of the flipped classroom teaching mode have reached the experimental presupposition.

7.3.1. Course Quality Is the Key Factor Affecting the Effective Implementation of the Flipped Classroom Teaching Mode.

The implementation of the whole teaching process of the flipped classroom teaching mode cannot be separated from the extensive and in-depth use of information technology, which requires us to put the concept of education informatization throughout the whole process of education and teaching. The Ten-Year Development Plan for Informatization of the Ministry of Education (2011-2020) also points out that it is a strategic choice for the development of education in China to promote the modernization of education-by-education informatization. It is of great significance for improving the quality of education, promoting educational equity, building a learning society and a powerful human resource country through building an information-based education system covering all kinds of schools in urban and rural areas, accelerating the popularization and sharing of high-quality educational resources, promoting the deep integration of information technology and education and teaching, and realizing the all-round innovation of educational ideas, concepts, methods and means. The flipped classroom teaching mode is to make full use of the advantages of communication and interaction of information technology platform, and combine high-quality online curriculum resources to comprehensively guarantee the improvement of teaching quality. In this sense, the flipped classroom learning platform should create such a teaching and learning environment as a user-friendly interface, convenient communication, smooth interaction, rich contents, real-time monitoring, multi-evaluation, timely feedback and scientific data generation functions [44]. Meanwhile, it should ensure the mobility of the learning platform and give full play to the advantages of mobile learning. Moreover, the online curriculum content setting should strive to be more hierarchical, operational and promotional, which is more conducive to in-depth learning. In other words, the curriculum setting should originate from the curriculum and go beyond the curriculum. Video resources for micro-courses should be made according to the key points and

difficulties of courses. The relevant curriculum resources should include not only the planned contents, but also the various examinations concerned by learners and the background information related to the courses. That is to say, online course resources should have depth, breadth and density [45].

7.3.2. Learners' Expectation Is the Driving Factor That Influences the Effective Implementation of the Flipped Classroom Teaching Mode.

According to ACSI theory, there are three observational variables that determine audience expectation: customer expectation, reliability expectation and overall quality expectation. Therefore, before preparing to carry out the flipped classroom teaching experiment for learners, we should make full prevenient conception and design, fully investigate learners' learning expectation goals, and finally accurately locate their specific expectation scope through analysis. Through the questionnaire survey, it is found that the learners' expectations of College English learning in higher vocational colleges are pluralistic [46]. On the surface, they expect to improve their listening, speaking, reading, writing and translating abilities comprehensively in their study, but in reality, they hope to pass all kinds of examinations smoothly including PRETCO (Practical English Test for Colleges) and test for upgrading from junior college to university in their hearts. In view of the future career intentions of higher vocational learners, it can be found that the widespread expectation of College English learners should be related to their professional learning and future career development. This requires us to fully implement the learner-centered teaching concept in teaching. In practical teaching, we should carefully explore and discuss the curriculum setting, the teaching materials screening, the selection of resources, the presentation of content, the assessment and evaluation, and truly embody the concept of public English learning serving the profession in teaching (See Table 3.).

Table 3. Statistics of Learners' Expectation for the Three Dimensions of College English Flipped Classroom

Observed Variables	Mean	Std. Deviation	T Value	Sig.
Learners' Expectation	3.47	1.15	-2.091	.041
Learners' Acceptance	3.38	1.25	-2.286	.045
Learners' Satisfaction	3.42	1.10	-2.140	.034

7.3.3. The Learners' Acceptance Is the Main Factor for the Effective Implementation of the Flipped Classroom Teaching Mode.

The results show that learners generally agree with and accept the College English flipped classroom teaching mode. Most learners are not only willing to accept the flipped classroom teaching mode, but also feel that the implementation of the flipped classroom teaching mode can improve their English ability, and they are satisfied with the flipped classroom teaching mode (See Table 3). The reasons are as follows: Firstly, we should change the rigid traditional classroom teaching mode to meet the different individual learning needs of each learner. Secondly, the flipped classroom truly embodies the

learner-centered teaching concept, learners' learning is more autonomous, and learning methods are more intuitive and repeatable. Thirdly, the flipped classroom can better combine pre-class autonomous learning with in-class presentation, and can comprehensively improve learners' comprehensive language ability [48]. Similarly, under the flipped classroom mode, learners can carry out pre-class learning at their own pace, which can better achieve and reflect the goal of teaching learners in accordance with their aptitude.

8. Conclusion

Based on SPOC teaching platform, this study explores the effectiveness of flipped classroom teaching mode from three dimensions: Learners' expectations, the acceptance of flipped classroom teaching mode and the satisfaction of teaching effect. By means of the methods of validity, reliability and regression factor analysis to collect, sort out, summarize and analyze the relevant experimental data, the research results through a one-year experimental study fully prove the correctness of the three research hypotheses, that is, vocational college students are extremely dissatisfied with the traditional English classroom teaching, and the flipped classroom teaching mode based on SPOC is full of expectations. Through the flipped classroom teaching of one year in the classroom teaching practice, students are more satisfied with the teaching effectiveness of this teaching mode, and their academic performance has increased significantly compared with the previous one. To this end, we conclude that if we want to effectively implement the flipped classroom teaching mode, achievement of high course quality is a key factor, high expectation of learners is an important driving force and the learners' acceptance towards the flipped classroom teaching mode is a main factor.

Undoubtedly, the flipped classroom is a new teaching mode, which develops rapidly in foreign countries and gradually drives to maturity. But in the field of education in China, it is still in the stage of exploration and trial [47]. Many colleagues in the educational circles have carried out various forms of educational and teaching experiments, which prove that the flipped classroom teaching mode reflects its due value in many aspects. For example, it can effectively improve learning performance, comprehensively improve learners' autonomous and collaborative inquiry ability, effectively meet learners' individual learning needs, realize the transformation of instructors and learners' roles and status, and help to cultivate learners' comprehensive learning ability, all of which are in line with the goals and requirements of education and teaching reform. However, due to the influence of traditional education and teaching ideas and the limitations of teaching software, hardware and technology, there are many difficulties in developing flipped classroom teaching mode in some areas of China. Definitely, if we want to further develop flipped classroom teaching mode in China, we must attach great importance to the following aspects:

8.1. Breaking through the Shackles of Information Technology Barriers

The effective development of the flipped classroom cannot be separated from the support of information technology. We should make every effort to develop and build various web-based learning platforms to provide learners with a good learning environment and high-quality web-based curriculum resources. However, the reality is unsatisfactory. Many instructors do not have the ability of information technology and cannot guarantee

the quality of the design, production and development of network curriculum resources. Moreover, many instructors are single-handed and do not build up a teaching team and community, which increases the burden of teaching for the majority of instructors. Therefore, when designing, building, developing and producing micro-video resources, it is necessary to extract knowledge points in advance [48]. Micro-class resources should be elaborately produced by aiming at teaching objectives, identifying key points, breaking through difficulties, and reflecting highlights. Micro-classes should be presented in the form of having the sense of humor and interest in order to attract learners' attention and stimulate learners' interest in learning. It is necessary to achieve the purpose of the practice of teaching activities, the case-based teaching methods and the sharing of teaching resources. At the same time, resource alliance should be established to lighten instructors' teaching burden.

8.2. Strengthening the Supervision and Guidance of the Pre-class Learning Process

The flipped classroom teaching has realized the transformation of teaching methods, instructors' and learners' roles and teaching time [49]. The absorption and internalization of knowledge are completed ahead of schedule. Learners can initially absorb and internalize knowledge through autonomous learning before class, which is the key stage to ensure the quality of learning. If the pre-class knowledge learning and initial absorption internalization cannot be completed in advance, it is difficult to ensure the effective implementation of presentation and in-depth discussion in class [50]. Therefore, at this stage, instructors must strengthen the supervision and management of learners and learning guidance, pay close attention to and interact with learners through the discussion area and notification area of SPOC learning platform to help learners complete the relevant learning tasks.

8.3. Keeping in Mind the Blindness of Following the Trend in the Choice of Teaching Modes

The emergence of each teaching mode has its own characteristics and advantages, but it also has its own limitations, which involves exploring the subject adaptability of the flipped classroom teaching mode. According to the relevant researches at home and abroad, it can be seen that the flipped classroom can be applied to the teaching of natural science courses such as physics, chemistry, biology, mathematics and social science courses such as language and art. It makes great difference to exploring some of the basic problems involved in these courses, understanding some basic concepts, guiding learning methods, memorizing knowledge and analyzing contents. Learners can basically master the knowledge system and framework by autonomous learning of micro-videos and other online courses before class. Extensive learning of curriculum can be accomplished through interaction and cooperation between instructors and learners [51]. However, for those courses with strong logicality, complicated reasoning process and strong specialty, it is necessary for us to seriously explore and think about how to carry out the flipped classroom teaching.

8.4. Extending the Scope of Time and Space of the Research and Increasing the Diversity of the Research

Due to the limitation of research conditions, the research sample is limited, and only 130 learners of different majors from the same college are selected to participate in the experiment. Furthermore, some learners have different personality needs because of their insufficient understanding of the flipped classroom, which requires us to further increase the sampling of the experimental research and expand the experimental group in future experiments. It is vital for us not only to consider the depth of the experiment, but also the breadth of the experiment, and try our best to meet the main needs of learners so as to achieve the stability and reliability of the research results.

References

[1] The State Council. Outline of national medium- and long-term education reform and development plan (2010-2020).
[2] Li, L. X. Research on promoting talent training in Applied Undergraduate Colleges and universities by "MOOC + flipped classroom". Heilongjiang Higher Education Research,2016 (6):136-138.
[3] Zhai, X. S. & Lin, L. L. Factor analysis of learner satisfaction in flipped classroom. China Educational Technology, 2014(4):104-105.
[4] Lu, L. N. "Flipped classroom": the challenge and reform path faced by the traditional classroom. University Education Science, 2014 (6):66.
[5] Lin, M. Q., Jiang, H. & Ren, C. Research on the development and reform of discipline evaluation. Higher education in China, 2010(21):43-44.
[6] Bergmann, J. & Sams, A. Flip Your Classroom: Talk to Every Student in Every Class Every Day. VA: International Society for Technology in Education, 2012, 34 (7): 13-14.
[7] Marco Renchetti. The VOLARE Methodology: Using Technology to Help Changing the Traditional Lecture Model. Tech-Education, 2010 (7):134-140.
[8] Jeremy F. Strayer. How Learning in an Inverted Classroom Influences Cooperation, Innovation and Task Orientation. Learning Environ Res, 2012(15):171-193.
[9] Robert T. Inverting the Linear Algebra Classroom. http://prezi.com/dz0rbkpy6tam/inverting-the-linear - algebra classroom, 2012-12-19.
[10] Xue, Y. & Zheng, L. Exploration and Reflection on the flipped classroom teaching mode based on SPOC. China Educational Technology, 2016(5):132-134.
[11] Dou, L. & Wen, S. Exploration of College English flipped classroom teaching reform based on app. Heilongjiang Higher Education Research, 2017(5):162-163.
[12] Lv, T. T. & Wang, N. Research on flipped classroom teaching model based on SPOC + Digital Teaching Resource Platform -- Taking College English as an example. China Educational Technology, 2016(5):123-125.
[13] Wang, J. J. Research on the flipped classroom teaching mode and its effect based on SPOC -- Taking "photography foundation" as an example. Modern Distance Research, 2018(1):44-46.
[14] Lu, Z. X. Research on the design of flipped classroom teaching mode based on m-learning. Journal of Chongqing Second Normal University, 2019, 25(1):146-147.
[15] Zeng, M. X. et al. Research on flipped classroom teaching mode based on MOOC. China Educational Technology, 2018(4):102-104.
[16] Zhang, Q. L.＆Wang, A. C. Research on New Hybrid Teaching Mode Based on Flipped Classroom. Modern Educational Technology, 2019, 24 (4), 30-31.
[17] Zhang, Q. An empirical study on the flipped classroom teaching model of College English based on "output driven". Teaching Research, 2020, 40(4):69-70.
[18] Meng, Y. M. English flipped classroom teaching mode under the Internet plus background. Exploration in Higher Education, 2017(12):60-61.
[19] Gan, P. & Hong, W. Y. Research on the application of flipped classroom based on micro class in Higher Vocational English Teaching. Vocational Education Forum, 2017(11):71-73.
[20] Zhu, Z. T., Guan, Y. Q. & Qiu, H. X. Domestic application practice and reflection of flipped classroom. E-education Research, 2018 (6):66-67.

[21] Wang, S. L. & Wu, M. Y. An analysis of the influencing factors of students' learning behavior under the flipped classroom model -- An Empirical Study Based on College English Teaching. Foreign Language Audio Visual Teaching, 2019 (177):27-28.

[22] Song, J. & Cheng, L. Research on PBL flipped classroom teaching model of College English under MOOC platform. Learning and Practice, 2020 (5):136-137.

[23] Wang, Q., Wang, Z. Y. & Liang, X. Y. A new flipped classroom teaching mode based on bullet screen classroom Discussion. Higher Education Forum, 2020 (5):24-26.

[24] Ning, Y., Zha, J., Shi, F. F. & Tang, Y. Innovation and practice of Hybrid Teaching Model of English flipped classroom in Higher Vocational Colleges under the environment of mobile network. Vocational and Technical Education, 2017, 38(35):39-40.

[25] Yu, Z. G. & Chen, W. T. Research on clicker Assisted College English flipped classroom. Foreign Language Audio Visual Teaching, 2018 (170):32-35.

[26] Zhang, Y. & Meng, Z. C. The value, limit and symbiosis of "guided learning case teaching" and "flipped classroom". Global Education Outlook, 2018, 42(7):10.

[27] Zhang, J. L. On the key factors of "flipped classroom" teaching mode. Distance Education in China, 2017 (10):59-60.

[28] Chen, F. Y. Flipped Classroom: Deep Integration of Information Technology Language Education. Educational Review, 2018, 25 (6), 28-29.

[29] Wang, S. L. & Wu, M. Y. An analysis of the influencing factors of students' learning behavior under the flipped classroom model -- An Empirical Study Based on College English Teaching. Foreign Language Audio Visual Teaching, 2019 (177):27-28.

[30] Zhu, H. J. & Zhu, Y. On flipped classroom and its effective implementation strategies. E-education Research, 2019 (8):79-80.

[31] Wei, D. X. Strategies for College English teachers to deal with flipped classroom. Educational Exploration, 2018 (12):39-40.

[32] Huang, J. Y. & Zheng, Y. X. "Flipped classroom" and the transformation of teachers' role. Shanghai Education and Scientific Research, 2020 (6):49-50.

[33] Gao, W. H. Flipped Classroom: from the construction of teaching model to the transformation of the role of university teachers. Contemporary Education Forum, 2018 (3):45-46.

[34] Liu, C. Y., Li, D., Zhang, B. R. & Hu, X. L. Systematic evaluation and meta-analysis of the effectiveness of SPOC flipped classroom teaching. Research on Open Education, 2019, 25(1):82-84.

[35] Armando Fox. From MOOCs to SPOCs. Communications of the ACM, 2018 (12):38-40.

[36] Coughlan, S. Harvard plans to boldly go with Spocs. http://www.bbc.com/news/business-24166247,2013-09-24.

[37] Ma, X. L., Zhao, G. Q. & Wu, T. Empirical research on public information technology in College Classroom. Journal of Distance Education, 2018 (1):79-80.

[38] Wan, M. An empirical study of flipped classroom model in College English Teaching. Exploration in Higher Education, 2016 (5):60.

[39] Zhong, X., Song, S. & Jiao, L. Research on teaching design based on flipped classroom idea in information environment. Open Education Research, 2018, 28 (1), 58-64.

[40] Jin, L. Salman Khan: how to flip the classroom. China Information Technology Education, 2012, 24 (10), 34-35.

[41] He, J. The practice and enlightenment of flipped classroom teaching mode: an empirical study based on College English teaching in Higher Vocational Colleges. Vocational and Technical Education, 2016, 35 (8), 34-35.

[42] He, J. Research and practice of flipped classroom teaching mode based on guidance case. Education and Information Technologies, 2020a, 25(6):2337-2335.

[43] He, J. & Ma, T. J. Research on the Integration of College English Teaching and Flipped Classroom. Harbin: The Polytechnic University of Harbin Press, 2018.

[44] Sun, M. H.＆Yang, Y. English Teaching and Flipped Classroom. Chang Chun: Ji Lin People＇s Press, 2018.

[45] Fang, Y. G. Requirements and Construction Strategies for Foreign Language Instructors in Higher Vocational Colleges under the Mixed Flipped Classroom Teaching Mode. Vocational & Technical Education Forum, 2016, 44 (26), 17-18.

[46] Wang, X. D. & Zhang, C. J. Z. The Applied Research of "Flipped Classroom" in College Teaching - Take the English Course of Educational Technology as an Example. Modern Educational Technology, 2018, 56 (8), 11-16.

[47] Ma, T. J.＆ He, J. Research and Practice of Flipped Classroom Teaching Mode Based on Guidance Case–an Empirical Study of Basic English Course. Jiang Su Education Research, 2017, 25 (10), 13-14.

[48] Huang, Y. L. Design of English Reading Classroom Teaching Activities in Higher Vocational Colleges under the Flipped Classroom Mode. Theory and Practice of Contemporary Education, 2017, 54 (5), 62.

[49] He, J. Construction of "three-stage asynchronous" instructional mode of blended flipped classroom based on Mobile learning platform. Education and Information Technologies, 2020b, 25(6):4915-4936.

[50] Li, C. Y. Exploration on the Practice of Mixed Instructional Design in Open Education under the Reversal Concept. Adult Education, 2018, 45 (9), 33-34.

[51] Hu, L. L. Mixed Teaching Based on Flipped Classroom and Peer Teaching. Academic Degree and Postgraduate Education, 2017, 44 (5), 54-55.

The Exploration of Blending Teaching of Engineering Cost Training Lesson in Private Vocational School

Yuanyuan CHEN [a,1], and Faxin HU [b]

ᵃ Sanya Polytechnic Vocational College, College of Intelligent Vehicles and Engineering, 572000, China
ᵇ Hainan United Zhenhua Land and Real Estate Appraisal and Consulting Company, Haikou City, Hainan Province, 570100

Abstract. Engineering cost has been a major issue in private vocational schools leading to problems like: lack of students learning initiative like a low self-learning ability, poor habit of preview before lesson, low attendance rate, short classroom listening time, low initiative to review after lesson, insufficient investment in practical training room, unreasonable teaching structure, high teacher mobility and inadequate teaching staff. The engineering cost practical training lesson adopts blending teaching construction and always penetrates the civic political elements. The teaching mode is online before the lesson, online and offline blending teaching mode during the lesson, and online teaching mode after the lesson. Blending teaching is great for improving the learning initiative and conscientiousness of private senior vocational students, alleviating the problem of insufficient investment in the training room of private senior vocational engineering costing major, alleviating the problem of unreasonable teacher structure, high teacher mobility and teacher shortage in private senior vocational engineering costing major.

Keywords. Blending teaching; Engineering cost practical training; private vocational school; Jianzhu Cloud lessons

1. Introduction

The policy of the Ministry of Education "Stopping without stopping teaching and learning", after COVID-19 outbreak in 2020, resulted in many colleges conducting the online lectures or offline recorded lectures where the students mainly study online. In the post-epidemic era, with repeated epidemics cycle the maturation of teachers'

cognitive, emotional, technological, pedagogical, and environmental aspects of online teaching have grown significantly.[1] However, especially for the engineering colleges, the practical training lessons in laboratories and workshops   could not fit the teaching objectives in online classes. Students can focus on knowledge and understand the industry frontiers however, the skill component is hard to imbibe in online teaching, even some students with high level of understanding practice face the problem of not understanding a certain operation steps or unable to continue the next operation in calculation software. So it's imperative for the engineering cost training lesson to explore a blending of online and offline teaching modes especially, in reading the drawings online, simple operation of the software, understanding the construction process, learning skills such as software operation in the offline classroom, handing on the knowledge and skills through a hands-on training platform after online lesson. Blending teaching can fit the new form of "Internet + education" with diversified and personalized teaching, stimulate students' independent learning motivation, save teachers time and make up for the lack of investment in practical training rooms for engineering costing major in private vocational school.

1.1 Problems of the private vocational school

A. Analysis of the academic state of affairs of students

Majority of the students of engineering cost major are male students, accounting for about 80-90%. Most of the students enter private vocational schools because they aren't fluent in English or they favor other subjects in high school.

In comparison to the undergraduate students, the private vocational school students are on the disadvantaged side of the high school entrance exam. In most of the cases, students with unsatisfactory scores in higher vocational schools enter private higher vocational schools. The students have to face interview in vocational schools with the tutors for entrance examination. The main reasons for the failure of private vocational school students in the college entrance examination include poor learning initiative and efficiency, low motivation, less initiative, unsound basic knowledge, average abstract, logical and image thinking abilities.

B. Insufficient investment in practical training rooms

According to the China Education Funding Statistical Yearbook of 2009-2019, the main source of funding for private universities is tuition fees, which accounts 60%-75% of the funding sources of private vocational school institutions. The national financial support for non-profit private vocational school institutions has shown a historical increase from scratch.[2] However, compared to the public schools, the financial support received by private vocational schools is still relatively small and hence, are very careful and economical in terms of practical training room investment. Except the hardware inputs such as computer room, drawing room, geotechnical room and construction technology training room, the engineering cost training room needs investment in software such as GTJ2021 volume, tendon unification software and cloud pricing platform GCCP6 software. It is hard for private universities to invest too much in the field of engineering due to less interest and investment inefficiency and try to save as much as possible and do not invest enough in software and hardware. Engineering cost practical training lessons are mainly taken in the computer room where, generally the configuration of the computers in the server room does not fit the

operating parameters of the software and fail to cater the needs of the students in lesson. Further, for the cost reason, the school just purchases few nodes, with an average of 2-3 students sharing one software node and in case of groups study, it is hard to get a teacher. The computer room is packed with lot of scheduled lessons and it is very difficult for the students to follow precise timing for practice leading to a significant reduction in the learning effect.

C. Engineering cost in private school

The private vocational schools have unreasonable teachers structure, less teachers and high teacher turnover.[2] Majority of the teachers are either retired veteran teachers or freshers and there are very few young and middle-aged teachers, since the latter prefer the public schools for better benefits. Besides, private vocational school teachers are more mobile and unstable due to issues such as bad treatment or development platform. Many old teachers are unfamiliar with the calculation software and pricing of the software, and unwilling to learn new things. The fresh recruits lack practical experience and show no tendency to learn in depth. Whereas, the part-time external teachers often transfer lessons in order to fit the project schedules. It is hard for educated and experienced teachers to stay in private vocational school due to the differences in the salary levels.

2. Construction of blending teaching

Blending teaching uses 5R method, the "right" learning techniques, incorporating "right" personal learning habits, and converting "right" skills to the "right" learners at the "right" time thereby, creating "a learning environment that combines face-to-face instructions and technology based media".[3] From the qualitative perspective, the blending teaching should be a mix of face-to-face teaching and thoughtful online teaching.[4] From the quantitative dimension, the proportion of online teaching in blending learning should be 30%~79%. If the online number of hours taught is greater than or equal to 80% of the total number of hours taught, the lesson is a fully online teaching and not a blending teaching.[5] The practicals in engineering and technical disciplines need to be completed in laboratories, engineering training centers or real production environments to understand the construction, growth and connection of one's knowledge and the improvement of professional practice skills.[6] Considering that the engineering cost practical training lessons need offline instruction to improve the application practice problems that can't be solved by online teaching, the proportion of such online teaching is usually around 30%-40%.

2.1 Blending teaching design

The engineering cost practical training lesson always permeates through the Civic Political elements; first, the teaching mode is online before the lesson, followed by online and offline with the blending teaching mode during the lesson, and online teaching mode after the lesson. The learning process should comprise of the post lesson certificate race integration, professional, industrial and vocational jobs docking. According to the concept of OBE, the result-oriented set of the professional content is aligned with professional standards in designing the teaching content with vocational standards and orienting the teaching process with the production process. Through

lectures by the corporate instructors, some students can also join the real corporate projects and dovetail academic certificates with vocational qualifications. Students can obtain the 1+X intermediate certificates in digital application of engineering costing at the elementary level and the seven major certificates. Vocational education can be dovetailed with lifelong learning, providing a platform for self-learning for students, developing their independent learning skills and problem-solving skills as shown in Figure 1.
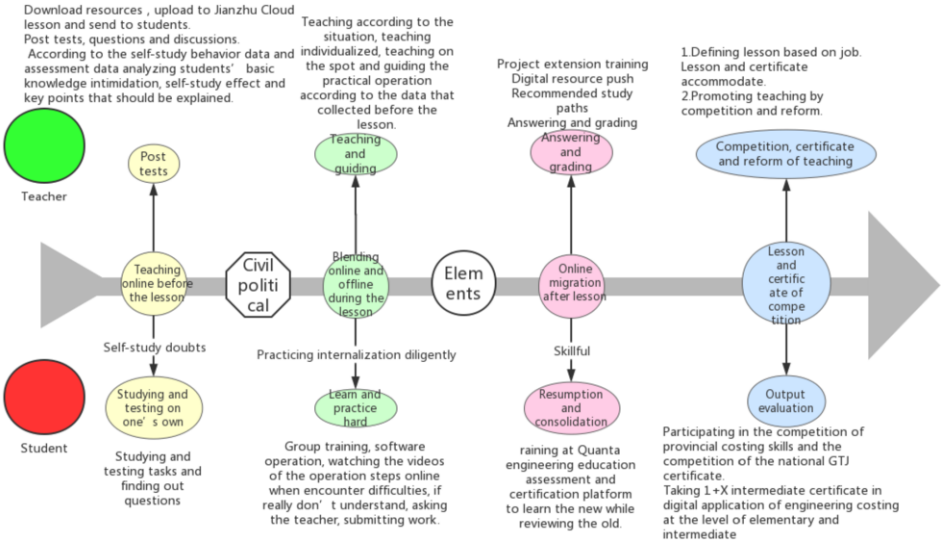

Figure 1 Blending teaching design of engineering cost training lesson

2.2 Selection of a suitable teaching platform

Off late, a variety of online teaching platforms are mushrooming such as, rain classroom, Xuexitong, China university catechism, wisdom tree, open lesson of Wangyi, Lanmo cloud lesson, Jianzhu cloud lesson, and so on. However, such complicated network teaching platforms should be trade-off and fit the requirements of the engineering cost practical training and the requirements of the private vocational school to save cost and facilitate students' learning abilities. Too many download applications on students' phones can confuse the students. Based on the characteristics of the profession, civil engineering majors are using the Jianzhu cloud lesson App. This App is free to use and has more systematic construction course, covering both theory and practice and is supported with teachers' lesson plans, students' learning videos and exercises. It can also record the whole teaching process, analyze the overall teaching effect and register the daily student's learning performance to make the teaching evaluation more objective. Besides, the Jianzhu cloud lesson App also has open functions and allows students to publish the import of external learning resources.

The teachers however, have a hard time to prepare the lessons in advance, need to search for the relevant courses from platforms such as wisdom tree, China university catechism, open lesson of Wangyi, Bilibili etc., download or record the relevant video resources and store them in the respective folders. Then integrate the existing video resources in the Jianzhu cloud lesson and combine the corresponding knowledge

content with micro-lessons to refine the design and put them together back on the online platform for the students. [7] At the same time, the engineering cost practical training involves the operation of software such as GTJ2021 volume, tendon unification software and cloud pricing platform GCCP6 software where, teachers can record videos of the software operation process in advance and explain the operation process while recording, so that students can watch and practice repeatedly. After all, learning the software isn't a quick thing, needs practicing and to know how it operates so that it can be used comfortably in the future work. The teacher can post the appropriate contents to the students in advance, so that students understand are in a position to operate the steps and facilitate classroom practice. At the same time, teachers should post tests, questions and discussions on the relevant topics to test the student's effectiveness. According to the survey, most of the private vocational school students show poor learning initiatives and engage in behaviors such as browsing their lessons. Hence, posting videos can engage the students and at the same time, the teacher must inform the students the importance of the course in the first lesson itself, so that the students will be involved whole heartedly in their future work. The teachers post the relevant contents such as tests and questions, discussions and so on which are simple and interesting and students are encouraged to answer the questions by watching the videos carefully. It is suggested that the teachers should find 1-2 backstage support teaching assistants to remind the students who haven't completed their tasks. If the student fails to study, the teaching assistant can call the student personally and supervise his study. Most students complete the task in time after reminders however few students need to be called multiple times to complete the assignments. After a semester of persistence, most of the students gradually develop study habits and improvise their independent learning ability.

Before the start of the lesson, teachers must prepare the lesson plan and understand the learning situation.[8] Teachers need to dynamically capture and precisely analyze the students' interests and concerns from the teacher-side data of the Jianzhu cloud lesson, and assess the students' learning ability and self-construct and students' motivation and behavior to gather information and explore their problems.[9] Based on the students' self-study behavior and assessment data, teacher can analyze the students' mastery in the basic knowledge, fears and self-study effectiveness to determine the key points to be covered in lesson.

Students must complete self-study and self-assessment before the lesson to identify the shortcomings and problems so that they can focus on learning in next lesson. Students who are interested in additional sub-course can also watch the recorded videos of the instructor in advance to understand the general procedure and prepare for lesson practice. It is worth noting that not all the courses are suitable for blending learning otherwise, it takes too much students' time and may lead to browsing unnecessary lessons and fail to achieve the desired teaching objectives. The schools should mainly choose some courses that are closely related to job positions and examination certificates so that students can realize the importance of such courses, study well and master the skills for future employment.

2.3 Online and offline integration of the lessons

Teaching during the lesson is the translation of modern educational theory into concrete implementation of blending learning programs, using blending teaching methods such as case study, scenario building, project conceptualization, group discussion,

task-driven process, role-playing, etc., to achieve a tacit understanding between teacher and students in an interactive classroom environment generating enlightenment, creativity, mutual construction of knowledge, and emotional integration.[9]

Teaching during the lesson is mainly offline and supplemented by online. According to the data collected before the lesson teacher will teach according to the situation and the material, teach on the spot and guide the practical operation. Teacher controls the student side, explains the relevant notes while operating the software, and releases the control for the students to practice the concepts. Some students can follow the steps to operate the software while others may operate a few steps and then forget them later. Encourage the students to open the instructional video pushed by the teacher to watch the operational steps. At this time students will be fully engaged, try to memorize and able to operate the software efficiently after practicing several times to achieve a better learning effect. If some students still don't understand how to operate after watching the video, the teacher can ask quick learners to assist them through peer learning, and improve the lesson efficiency.

Since the private universities work under cost constraints, the software training is conducted in groups of 2-3 students per node. This situation can be resolved, by encouraging the students to participate in the 1+X engineering costing digital application junior intermediate certificate examinations and the national GTJ Skills certification competition for private vocational school institutions. This will enable students to get a cloud lock for a certain amount of the time by signing up and logging into the software from their own cell phone. Students who are interested in studying well will use this approach to facilitate their learning in lesson and practice after lesson. Alternatively, students who don't have a cloud lock account can be divided in groups of two and study together. One student may open the drawing and other student may operate the software. The student who opens the drawing shares his or her partner the drawing information so that the partner can easily enter the relevant parameters. After completing the batch selection then delete it and exchange roles to practice again. This can result in a substantial improvement in the students' ability to read and operate the software. This however, will require the computer room with internet facility and block out games to avoid students' distraction. This will enable students to watch the operation steps online and in case of any difficulty, can ask the teacher and submit their work.

The grade evaluation of offline practical training operations can induct a three-in-one comprehensive evaluation system of "student self-assessment, student-student mutual evaluation and teacher appraisal". On the one hand, it can effectively compensate the shortcomings of the teacher's strong subjectivity in grading, and also allow students to clearly understand their own strengths and weaknesses, stimulate the sense of competition and motivate students to attend lessons further. [10]

2.4 Grading, student review and consolidation

The main task after completion of the lesson is the transfer and extension of the knowledge structure. Students can participate in course knowledge base interaction and knowledge consolidation through mobile instant messaging. Teachers should pay attention to the expected satisfaction and actual completion rate of the students' learning enhancement, conduct attribution analysis and dynamically issue learning quality alerts.[9]

Teachers should post some relevant extension resources outside the classroom after the experiment for interested and academically capable students to study independently besides online interactive discussions with students on the platform to answer their questions and solve their problems.[11] During the teaching process, teachers should combine differentiated "learning" to create a conducive atmosphere for students' individual thinking and exploration. Teaching according to the "student" concept can help learning with differences in order to develop the awareness and inculcate independent thinking ability and cooperative learning so that each student can achieve value-added growth from his original foundation.[12] For students with great learning levels, teacher can push the project extension training on the Jianzhu cloud lesson App and students practice drawing-related content on the software in conjunction with what they have learnt. Students learn to draw inferences about other cases from one instance, contact with different drawings can improve the ability to read drawings, reduce the fear of facing different new drawings at work, think about the calculation process, and log in to the software operations. On the other hand, for general students teacher can push related notes and quicker methods of operation for the corresponding part of the work recorded by the school-enterprise cooperation teachers, in addition to relevant operation videos on the Jianzhu cloud lesson App to encourage and involve students to watch and think. For students with average mastery, the school should ask them to review the software operation video posted before the lesson to consolidate and master the basic operation steps. Teachers can answer questions in unison at a set time to facilitate individualized instructions. Though the individual student requirements vary but, this process guarantees that everyone gets respective value addition and know the basic software operations. Using this online and offline blending teaching, students are guided to conduct inquiry-based and personalized learning through the online course platform to enhance their independent learning ability.[13] Students practice on the Guanglianda engineering education assessment and certification platform to learn from the past and master the operational skills. The Quanta has explanations of relevant break-in tasks and also automatically generates scores after students complete the software operations. According to the scores, students can practice repeatedly and can ask their roommates or consult with Guang Xiaoer to overcome difficulties or ask student assistants and teachers to successfully pass the breakthrough with high scores.

3 Promotion of blending teaching

Blending teaching is conducive to improve the learning initiative and self-motivation of private vocational school students and helps to alleviate the problem of insufficient investment and unreasonable teacher structure, high teacher mobility and teacher shortage in private vocational school engineering costing major.

3.1 Developing learning initiative and self-motivation

The blending teaching lesson is based on online teaching before the lesson, which gradually helps private vocational school students to develop previewing habit and improving their initiative and enthusiasm in learning. To promote the student learning, it is necessary to increase the level of his learning engagement, which is an important element for the academic success.[14] The school should gradually guide students to

create awareness of independent learning and gradually improve their independent learning ability. To face the future uncertainty and the ever-changing progress of science and technology, students need to cope gradually with the unknown world and slowly adapt to these changes in their jobs. Teachers gradually help students to change their learning concepts and change the erstwhile situation of passive learning by blending courses, exert fully their own learning in the subject and enhance the awareness of independent learning. The blending learning methods and empower teachers to guide students to set moderate learning goals; steer them to learn to observe, think and practice while acquiring knowledge; help students to enhance their reflection on learning by identifying progress and shortcomings, and evolve strategies to improve effective learning.[15] More importantly, while facing the bombardment of complex information, it is hard for students to find a suitable learning platform where they want to improve after working. The Jianzhu cloud lesson APP constantly uploads new resources, updates its contents by adding various lectures to equip them with the frontier of the times. According to the survey of private high school graduates, many students realize that they are lacking in a certain areas of their profession and want to relearn the relevant knowledge and content after stepping into work and habitually prefer the Jianzhu cloud lesson App in their spare time to consolidate and improve themselves. All of this was made possible by the platform provided by blending learning and the improvement of students' independent learning skills through subtlety. Transforming their extrinsic motivation to learn into intrinsic motivation by strengthening their sense of professional identity and developing the ability to solve the practical problems in real work and lifelong learning ability.[16]

3.2 Alleviating insufficient investment problem

In order to overcome the difficulty of insufficient software nodes in the training room and less time slots for computer practice, for every lesson a team of 20-30 students are allowed to participate in the annual national GTJ skills certification competition for higher education institutions. Students receive several months of access to the cloud lock. Computers are now more popular in the private vocational schools and students can login their Cloud lock accounts in the dormitory or the library to practice hands-on work with the software. Students can view the steps of the software before the lesson, learn and practice during the lesson and download different drawings for practice after the lesson, plus the instructor conducts intensive training for the pretest before the competition to obtain the 1+X Intermediate Certificate in Digital Application of Engineering Costing for Beginners. After the post course certificate race integration, students further strengthen the training and receive the competition's winning certificate and the newly introduced 1+X Intermediate Certificate in Digital Application of Engineering Costing for Beginners hence, not only their learning accomplishment is created but a solid foundation is also laid for future employment.

3.3 Managing problems of teacher structure

Blending teaching is conducive to alleviate the problems of insufficient investment in teacher training and unreasonable teacher structure in the private vocational school. Uploading resources before a blending learning session is a major challenge for teachers, it requires them to locate videos and teaching materials for the related courses and is also a process of continuous self-improvement for teachers to acquire external

knowledge on the subject. In the China university catechism, open lesson of Wangyi and the Jianzhu cloud lesson APP videos are recorded by some famous teachers, who worked on the teaching content, design, and methods. This not only aids teachers' professionalism but also makes up the problems of insufficient investment, quality and teacher turnover in private vocational school. The private vocational school engineering cost practical training lesson is mainly taught by the newly recruited young teachers do make a conscientious effort to collect resources and form a library of teaching resources, even when these teachers leave the resource libraries are still available to new fresh recruits for reference purposes. The external adjunct teachers also continue to expand the teaching resource base by uploading some non-confidential real-world projects from the companies. This will alleviate the discontinuity caused by high teacher turnover. The amount of lesson hours for private vocational school online courses, in general, is rarely or hardly counted. Only the first course is given as a project with certain financial support however, subsequent online courses of the same kind are not counted as hours. Taking the engineering cost training course as an example, it has 64 class hours and is taught in separate classes. There are approximately one-third of the 21 credit hours online courses, however, these 21 credit hours do not count as a teacher's workload. In order to complete the teaching workload for the whole year, teacher has to increase the number of courses taught. Particularly in shortage of teachers the school may choose more online courses, which can save teachers in the case of fitting the basic teaching.

References

[1] Zhang Qianwei, Zhang Min, Yang Chunxia (2022). The Status, Challenges and Suggestions of Blended Teaching Readiness of College Teachers [J]. Electrochemical Education Research, 2022, 43(01): 46-53.
[2] You Zihuan (2021). A view of Financial Aid for Nonprofit Private VocationalEducation Institutions [D]. Hubei University of Technology, 2021.
[3] Yang Hao, Fu Yanfang (2017). Analysis of the practice and effect of microlearning based on blending teaching [J]. Vocational and Technical Education in China, 2017(17): 45-49.
[4] Garrison D R，Kanuka H (2004). Blending learning: uncovering its transformative potential in higher education [J]. Internet and highereducation, 2004, 7(2):95-105.
[5] Allen I. E., Seaman J., (2010). Lesson differences:online education in the United States [EB/OL]. [2010-11-21]. https://secure.onlinelearningconsortium.org/publications/survey/lesson_differences.
[6] Zhao Chun, Liu Fugang (2021). A blending teaching model integrating with the connectivism and neo-constructivism [J]. Exploring higher education, 2021(10): 16-21.
[7] Hong Linjun, Xu Zheng, Gu Ting, Huang Sixiu, Cai Gengyuan, Liu Dewu (2022). Exploring the blending teaching of "Pig Breeding" course based on microlearning [J]. Journal of Animal Ecology, 2022, 43(01): 94-96.
[8] Lin Jian (2022). Informatization of engineering education [J]. Research of higher engineering education, 2022(01): 1-10.
[9] Mei Luhai (2021). Empirical research of the quantitative system of performance evaluation of blending teaching mode in private vocational education [J]. Vocational and technical education, 2021, 42(32): 48-52.
[10] Dai Minghua, Zhang Hongzhe, Liang Yande, Wang Yongqing, Liu Kuo, Cui Enming(2021).Exploration of online and offline blending advanced manufacturing technology practical training teaching [J]. Laboratory research and exploration, 2021, 40(06): 150-153+227.
[11] Duan Haijuan, Wang Ying (2021). Exploring the blending teaching of civil engineering materials laboratory lesson based on ADDIE model [J]. Laboratory research and exploration, 2021, 40(08): 159-162.
[12] Zhu Su, Liu Fahu, Han Bin, Zhang Xiaoyan, Gu Jia (2020). Research on the study of private vocational school students' learning input in the context of high quality development--based on the data of CCSS empirical survey in W vocational college [J]. Vocational and technical education, 2020, 41(34): 24-29.

[13] Kuang Jianghong, Feng Xiumeng (2021). Blending teaching design for engineering courses in local applied private vocational school [J]. Laboratory research and exploration, 2021, 40(06): 232-236.

[14] Yi Chenxi, Shen Qiyun, Li Wen, Hu Shunyi (2021). Survey and suggestions on the current situation of students' learning commitment in private vocational schools - survey on learning situation of helping learning course development [J]. Vocational education forum, 2021, 37(01): 69-78.

[15] Suo Chenglin (2021). Problems and countermeasures of blending teaching in private vocational school [J]. Educational theory and practice, 2021, 41(12): 25-27.

[16] Li Yan, Gao Fan, Yang Chenhui, Yang Guoli (2017). Research on the academic situation of higher vocational civil engineering and water conservancy students [J]. Vocational education forum, 2017(21): 23-27.

Investigation and Analysis for Self-Directed Learning of Backbone Teachers in Primary and Middle Schools

Jisheng He, Manyi Chen[1] and Jiaming Zhong

Xiangnan University, Chenzhou, Hunan Province, 423000, China

Abstract. [Purpose] to discuss about the self-directed learning readiness of backbone teachers in primary and middle schools, and its relationship with their learning effectiveness. [Methods] "scales for teachers' self-directed learning readiness" and "questionnaires about teachers' in-service training effects" were conducted on 592 primary and middle school backbone teachers who were receiving National Teacher Training Program. [Results] The self-directed learning readiness of primary and middle school backbone teachers is commonly high; the readiness differs in different genders, teaching ages, and between rural and urban areas; there is significant positive correlation between the teachers' self-directed learning readiness and their learning effectiveness. [Enlightenment] Supportive system for self-directed learning should be created, to encourage and lead backbone teachers in primary and middle schools to achieve self-directed learning with high efficiency.

Keywords. Teacher training, self-directed learning (SDL), learning effectiveness, backbone teachers in primary and middle schools

1. Introduction

The concept of self-directed learning (SDL) comes from adult education, which is an educational method and learning method on the basis of adults' learning characteristics.[1] The SDL is the awareness and ability to determine learning targets and contents, seek learning resources, apply effective learning strategies, and evaluate learning results on their own. It is a new learning idea that has been put forward to comply with the learning society, knowledge economy, and lifelong education. Researches have shown that SDL learners feature powerful learning expectations, can conduct independent learning, have independent learning ability and skills, can formulate reasonable learning schedules, and can keep on learning. However, self-directed learning readiness refers to the awareness that learners can have the ability and expectation of formulating learning plans, carrying out and evaluating their learning activities by themselves. That is the degree of effective self-directed learning. [2] Self-directed learning readiness is the most important indicator to measure the SDL level.[3]

The training of backbone teachers in primary and middle schools is a significant measure to help primary and middle school teachers develop to research-based and expert teachers through selection and key training, which begins at the end of 1990s and the early 21st century. Backbone teachers in primary and middle schools are excellent teachers and the mainstay in schools.[4] Their quantity and quality can not only reflect the overall level of the teaching group, but also forms a connection between experienced teachers and inexperienced teachers, which is the core of pushing forward the reform and development of elementary education. The training of backbone teachers is divided into four platforms: the national level, provincial level, municipal level, and county level. As a kind of honor and a group of teachers with high academic level and strong teaching and research ability, backbone teachers should possess powerful independent learning and research ability. Therefore, these teachers must possess strong awareness and ability of self-directed learning. Meanwhile, the training of backbone teachers and their continuous learning after training belong to typical adult learning which features self-directed learning, so the level of self-directed learning readiness directly influences their learning effectiveness, as well as their teaching and research effects. What's more, the authors once undertook the training of backbone teachers at provincial and municipal level. [5] Based on this, this research aims to discuss about the self-directed learning readiness of backbone teachers in provincial and municipal primary and middle schools, as well as its relationship with learning effectiveness.

2. Research Methods

2.1 Research Targets

The research targets are some of the backbone teachers from provincial and municipal primary and middle schools in Hunan Province who had received training from 2001 to 2005. In this research, 620 questionnaires were handed out, with 602 collected back, among which 592 were effective questionnaires. Among the research targets, there were 242 male teachers and 350 female teachers, with their average age of 32.8 years old and average teaching age of 11.8 years old.

2.2 Research Tools

Based on the "Scale for Self-Directed Learning Readiness of Teachers" and the "Questionnaire for Teachers' In-Service Training Effect" that are formulated by Mingchang Cai from Nanhua University, Taiwan, this research revises some contents and wording to form the final questionnaire for investigation. [6] These two questionnaires adopt the scoring method of five-point scale, from "1—very inconsistent" to "5—very consistent". The theoretical median is "3", representing "half consistent".

(1) Questionnaire for SDL readiness: this questionnaire consists of 27 items, which are used to investigate five components of SDL readiness for backbone primary and middle school teachers, namely positivity, independence, creativity, challenging, and liking. The positivity refers to learners' awareness and ability to actively take part in learning activities; independence refers to the awareness and ability that learners can select their learning contents and learning methods in line with their needs; creativity is the

awareness and ability for learners to try something new and engage in learning activities with unique learning methods; challenging is the awareness and ability for learners to face the difficulties in their learning; while liking refers to the awareness and ability for learners to learn happily. Through investigation, the Cronbach a coefficient of teachers' SDL readiness questionnaire is shown in Table 1. From the statistical result of Table 1, we can see that the questionnaire for SDL readiness of backbone teachers in primary and middle schools features high internal consistency, so it is reliable.

Table 1   Cronbach a Coefficient of Teachers' SDL Readiness Questionnaire

Dimension	total amount	positivity	independence	creativity	challenging	liking
a coefficient	0.90	0.81	0.83	0.79	0.76	0.74

(2) Learning effectiveness questionnaire: this questionnaire consists of 26 items, which are used to investigate backbone teachers' learning fruits in terms of professional education competence, academic ability, professional attitude, and common ability, to from the total score for learning effectiveness. Through verification, the Cronbach a coefficient of teachers' learning effectiveness questionnaire is shown in Table 2. From the statistical results, we can see that the questionnaire for primary and middle school teachers' learning effectiveness features high internal consistency, so it is reliable.

Table 2   Cronbach a Coefficient of Teachers' Learning effectiveness Questionnaire

Dimension	total amount	professional education competence	academic ability	professional attitude	common ability
a coefficient	0.92	0.91	0.84	0.85	0.80

3. Research Results

3.1 Normal situation of SDL readiness for primary and middle school backbone teachers

The scoring situation of SDL readiness questionnaire for primary and middle school backbone teachers is shown in Table 3.

Table 3   Basic Situation of SDL Readiness for Primary and Middle School Backbone Teachers

	Number of items	mean (M)	standard deviation(SD)
positivity	9	4.30	0.59
independence	6	4.15	0.54
creativity	5	3.80	0.60
challenging	3	3.51	0.68
liking	4	4.26	0.52
SDL Total average of readiness	27	4.01	0.59

Table 3 shows that the level of SDL readiness of primary and middle school backbone teachers is relatively high, which reaches the level of "4—basically consistent". When

talking about the five components of SDL readiness, it surpasses the level of "basically consistent" in terms of positivity, independence, and liking; however, it achieves low score in creativity and challenging, but higher than the theoretical median "3". All in all, the level of primary and middle school backbone teachers' SDL readiness is high.

3.2 Difference Test for SDL Readiness of Primary and Middle School Backbone Teachers

Independent sample t test is conducted on the gender difference, teaching age difference, and differences between rural and urban areas of teachers' working unit in terms of the five components of primary and middle school backbone teachers' SDL readiness in this research. The results are shown as follows:

(1) Gender difference of SDL readiness of primary and middle school teachers
    The difference of SDL readiness between male and female backbone teachers is investigated in this research. The results are shown in Table 4.

Table 4   Gender Difference of SDL Readiness of Primary and Middle School Backbone teachers

	Male backbone teachers (242persons)		female backbone teachers (350 persons)		
	Mean(M)	standard deviation (SD)	Mean(M)	standard deviation (SD)	t value
positivity	4.24	0.54	4.35	0.56	-2.812**
independence	4.10	0.52	4.26	0.54	-3.012**
creativity	3.94	0.60	3.70	0.64	1.824*
challenging	3.62	0.71	3.45	0.72	2.120*
liking	4.28	0.51	4.25	0.61	1.174

Remark: $*P < 0.05$, $**P < 0.01$, $***P < 0.001$, and the same as follows.

    Table 4 shows that female backbone teachers are better than male backbone teachers in terms of the positivity and independence of SDL readiness, while male backbone teachers are better than female backbone teachers in terms of creativity and challenging.

(2) Teaching Age Difference of SDL Readiness of Primary and Middle School Backbone Teachers
    The differences of SDL readiness between the backbone teachers with no more than 10 years' teaching age and those with more than 10 years are investigated in this research. The results are shown in Table 5.
    Table 5 shows that the backbone teachers with more than 10 years' teaching age are better than those with no more than 10 years' teaching age in terms of the positivity and liking of SDL readiness. There was no significant difference in autonomy, creativity and challenge.

Table 5 Teaching Age Differences of SDL Readiness of Primary and Middle School Backbone Teachers

	No more than 10 years' teaching age (312 persons)		more than 10 years' teaching age (280 persons)		
	Mean (M)	standard deviation(SD)	Mean(M)	standard deviation(SD)	t value
positivity	4.22	0.56	4.33	0.54	-1.812*
independence	4.18	0.55	4.25	0.52	-1.314
creativity	3.75	0.61	3.86	0.60	-1.592
challenging	3.56	0.72	3.57	0.71	-0.092
liking	4.12	0.51	4.25	0.54	-2.682**

3.3 Region Difference of SDL Readiness of Primary and Middle School Backbone Teachers

The differences of SDL readiness between the backbone teachers working in urban areas (cities, counties) and rural areas (towns, villages) are investigated in this research. The results are shown in Table 6.

Table 6 Rural-Urban Difference of SDL Readiness of Primary and Middle School Backbone Teachers

	Urban schools (381 persons)		rural schools(211 persons)		
	mean (M)	standard deviation(SD)	mean(M)	standard deviation(SD)	t value
positivity	4.31	0.54	4.28	0.52	0.526
independence	4.24	0.56	4.19	0.53	1.304
creativity	3.89	0.71	3.76	0.70	2.121*
challenging	3.58	0.70	3.47	0.69	2.218*
liking	4.26	0.53	4.25	0.55	1.542

From Table 6, we can see that urban backbone teachers are better than rural backbone teachers in terms of creativity and challenging of SDL readiness. There were no significant differences in positivity, autonomy and liking.

3.4 Relationship between SDL Readiness of Primary and Middle School Backbone Teachers and Their Learning effectiveness

This research verifies the correlation coefficient between the SDL readiness of backbone teachers and their learning effectiveness during the in-service training period. The results are shown in Table 7.

Table 7 Correlation between SDL Readiness of Primary and Middle School Backbone Teachers and Learning effectiveness

	positivity	independence	creativity	challenging	liking	total score SDL readiness
Total score of learning effectiveness	0.512***	0.453***	0.395***	0.415***	0.397***	0.521***

From Table 7, we can see that SDL readiness of primary and middle school backbone teachers and its five components are positively correlated to learning effectiveness. That is to say, the higher SDL readiness of backbone teachers is, the better learning effectiveness will be.

4. Discussion, Analysis, and Enlightenment

4.1 Current Status of SDL Readiness of Primary and Middle School Backbone Teachers

The research results show that the total score of SDL readiness and the score of its five components are high, indicating that primary and middle school backbone teachers have powerful SDL readiness. This is one of the necessary qualities of backbone teachers in primary and middle schools.

Ranking from top to lower level, the scores for five components of SDL readiness are as follows: positivity, liking, independence, creativity, and challenging. Meanwhile, the score of creativity and challenging is lower than "4", which indicates that there is large room for the improvement of SDL creativity and challenging. However, teaching is a creative task, so creativity and challenging are important features of teaching. Therefore, it is of great significance to inspire and develop the creativity and challenging of SDL of primary and middle school backbone teachers. First, it meets the needs of teachers' development. Second, it satisfies the needs of education. Only the teachers with high SDL level of creativity and challenging can cultivate the students with high SDL level of creativity and challenging. Therefore, we must focus on cultivating the creativity and challenging of SDL for primary and middle school backbone teachers. Meanwhile, training schools should consciously open some SDL courses, hold some professional lectures or workshops, or set up academic groups of teacher educators (teachers from the training schools). The schools that backbone teachers work in should organize some activities according to real situations, so that they will continuously improve their SDL creativity and challenging. In this way, they will become SDL learners with higher level, which can lay solid foundation for the development targets and occupational development targets of "scientific-based teachers" and "expert teachers".

4.2 Difference Analysis for SDL Readiness of Primary and Middle School Backbone Teachers

The research has found out that SDL readiness of primary and middle school backbone teachers has great differences in gender, teaching age, and the rural-urban difference of working unit.

(1) Female backbone teachers are better than male backbone teachers in terms of the positivity and independence of SDL readiness, while male backbone teachers are better than female backbone teachers in terms of creativity and challenging. The reason lies in that different genders have different psychological quality and social features. Their attitudes towards learning that are shaped during their long-term learning and teaching practice are different, and their personality tendency and aptitude that are formed through long-term personality development and socialization process are different. For

instance, female teachers are more hard-working, earnest, and conscious in terms of learning attitude and willingness. Male teachers have more active thinking ability, so their attitude to learning is more flexible and open. What's more, male backbone teachers are better in self-planning and self-reflection, which may be an important reason for better creativity and challenging of male backbone teachers in terms of SDL readiness. Therefore, both male and female backbone teachers must learn from each other and complement each other, to continuously improve themselves and perfect themselves.

(2) The backbone teachers with more than 10 years' teaching age are better than those with no more than 10 years teaching age in terms of the positivity and liking of SDL readiness. The teachers with more teaching age usually have more problems and puzzles, because they have engaged in teaching for a long time, and they have accumulated enriched teaching experience. In this way, they are in urgent need to receive further training to replenish, supply, and update their concepts, knowledge, and skills, and to solve their problems and puzzles. Once they get the chance of further training, they will cherish this chance, and perform more active, positive, and devoted. Therefore, the backbone teachers with more than 10 years' teaching age can achieve higher score than those with shorter teaching age in terms of the positivity and liking of SDL readiness. In other words, younger teachers with shorter teaching age are suggested to learn from the teachers with longer teaching age, so as to speed up their growth rate.

(3) Backbone teachers in urban schools are better than those in rural schools in terms of creativity and challenging of SDL readiness. Due to regional (including schools) requirements for their jobs, backbone teachers in urban schools have received stricter requirements and training in their long-term teaching practice, so it is more challenging for them to overcome all kinds of difficulties in their life and work. During this process, they will perform stronger creativity, so it is reflected on the creativity and challenging of SDL readiness. The quality difference between rural and urban teachers is one of the reasons of different teaching qualities between rural and urban schools. To speed up new rural construction (including rural education) nowadays, the quality of backbone teachers in rural schools should be enhanced, so as to improve the teaching quality of rural schools. Therefore, these teachers will set good examples for rural schools, thus pushing forward the improvement of overall qualities of rural school teachers.

4.3 Relationship between SDL Readiness of Primary and Middle School Backbone Teachers and Their Learning effectiveness

Viewing from related inspection results, the SDL readiness of primary and middle school backbone teachers and its five components are positively correlated to their learning effectiveness, indicating that the higher SDL readiness is, the better learning effectiveness will be. The positivity, independence, and challenging of SDL readiness of primary and middle school backbone teachers has the largest correlation coefficient with learning effectiveness, indicating that the positivity, independence, and challenging of their SDL readiness have more powerful influence and contribution to them. As backbone teachers in primary and middle schools shoulder heavy teaching tasks, and some backbone teachers are even engaged in administrative management, with relatively old age, they are real "old students". Therefore, they have to overcome many difficulties, no matter about training or the "in-service learning" after training. [7]

So it is a huge challenge for them, no matter in time, energy, or ability. In other words, if backbone teachers in primary and middle schools possess positive learning attitude, can learn in an independent, self-disciplinary, and conscious way, and dare to face and challenge all kinds of difficulties in life, their learning effectiveness will be greatly promoted.

4.4 Create Learning Supportive Systems for SDL of Backbone Teachers, to Encourage and Lead Highly Efficient SDL

The schools that backbone teachers work in and the training schools should create learning supportive systems for self-directed learning, which can provide sufficient books, resources, and favorable learning environment to them, and can also encourage and lead backbone teachers to achieve highly efficient self-directed learning. The specific reflection is shown as follows:

(1) Training schools should help backbone teachers to master the methods and technology of literature search and information inquiry, and cultivate their ability of searching resources. The schools that backbone teachers work in should try their best to help teachers get access to books, journals, and database information network.

(2) The schools that backbone teachers work in should link their learning effectiveness with the appraisal for excellent performance and promotion.

(3) Offer teaching support. Teacher educators should not only act as lecturers, but more of instructors and promotors. [8]

① Offer problem-oriented teaching support. Teacher educators should encourage backbone teachers to raise their problems and puzzles, and then inspire their enriched educational and teaching experience through the problems and puzzles. Through communication and reflection, backbone teachers would find out the rules about education and teaching, and master the skills of education and teaching, to promote their awareness and ability of SDL.

② Offer research project-oriented teaching support. Teacher educators select appropriate research projects and serve as declarants. Then, the project is divided into several sub-projects, and backbone teachers shoulder the task of doing research or experiment. During the research project, the training process includes the whole process of making research project or doing experiments, ranging from theoretical learning, lecture learning, information collection, and workshop participation, to cultivate backbone teachers' innovation and practical ability. Therefore, their awareness and ability of SDL can be improved.[9]

③ In the process of education and teaching, teacher educators guide backbone teachers to learn some skills and methods of setting up learning targets, formulating learning plans, seeking learning resources, applying effective learning strategies, making self-evaluation, and inspiring academic motivation. [10] The schools that backbone teachers work in should also encourage and lead them to apply the SDL knowledge and skills they have mastered to their education and teaching practice, so that the teachers and their students can gradually form the awareness and ability of independent learning and lifelong learning.

References

[1] Zhou Xiaoyan. Cultivating Responsible Learners--Basic Ideas of Self-Directed Learning and Its Pedagogical Significance [J]. Journal of Tianjin Academy of Educational Science, 2005(1).

[2] Cai Mingchang. A Study on the Relationship between Middle School Teachers' Self-Directed Learning Readiness and Their In-Service Learning effectiveness [J]. Educational Research Information (Taiwan) 2001 (4)

[3] Luan Juan. Self-Directed Learning: The Consciousness of Leading Teachers to Development [J]. Jiangsu Education, 2021(9).

[4] Zhou Kehan. Study on Teachers' Self-Directed Learning under Network Environment [J].Journal of the College of Northwest Adult Education, 2021(5).

[5] Xiong Wei, Xiao Qiyong. The Connotation, Dilemma, and Promoting Strategies of Primary and Middle School Teachers' Self-Directed Learning [J]. Journal of Educational Development, 2021(03).

[6] Zhou Jie. New Expectations of Adult Self-Directed Learning on the Role of Teachers [J].China Adult Education, 2019(09).

[7] Liu Shibin, Wang Yingying. Investigation and Study on High School Teachers' Self-Directed Learning—Take Xinxian County, Shandong Province as an Example[J]. Lifelong Education Research, 2019(08).

[8] Dong Xiaoyu. Investigation and Study on Self-Directed Learning Ability of Young Rural Primary School Teachers in Tianjin [J]. Journal of Zhejiang Normal University [D].2019.

[9] Zhang Peijia, Liu Jianqing. Current Situation and Thinking of Teachers' Professional Development Based on Self-Directed Learning—Take Primary School Teachers in Pingdingshan City as an Example [J]. Journal of Continuing Higher Education, 2019(04).

[10] Wang Yanmei. The Value of Teachers' Self-Directed Learning to Rural Teachers' Professional Development [J]. Comparative Study of Cultural Innovation, 2018(09).

The Application of Formative Evaluation to Online Teaching of "Doctor-Patient Communication Skills"

Zuyun Zeng, Fang Hu,[1] Jisheng He and Wenting Yan
Xiangnan University, Chenzhou City, Hunan Province, 423000, China

Abstract. Purpose: to investigate the application of formative evaluation to online teaching of "Doctor-Patient Communication Skills". Methods: taking three classes of students majored in Medical Imaging Technology (entered our college in the year 2018) as the research objects, who are divided into the experimental group and control group. The experimental group focuses on the teaching method of online formulative evaluation, while the control group centers on face-to-face classroom teaching. Contrastive analysis is conducted on the online learning of experimental group, including online independent learning, online interaction, module completion, chapter test, and final exam results. Then, the final scores of students in each group are compared. Through questionnaires in each class, students' assessment about formative evaluation of online teaching and classroom teaching is compared. Results: by contrasting the satisfaction of teaching methods and the satisfaction of self-evaluation, the experimental group is better than contrast group ($P<0.05$); by contrasting theoretical score, the experimental group is higher than the contrast group ($P<0.05$); the teaching ability of members in experimental group is better than that of contrast group ($P<0.05$); the CTDI-CV score of students in experimental group is obviously higher than that of the contrast group ($P<0.05$). Conclusion: Formed in the doctor-patient communication skills online teaching evaluation scheme applied value, students can very clearly know oneself in the course of the study situation, timely reflection, find out the deficiencies, lessons learned, at the same time making efforts in the direction of the next stage and target, at the same time, teachers can grasp the characteristics of formative assessment, according to the result of formative assessment, Grasp the analysis and improvement of students' learning process in teaching practice and help formulate more effective teaching methods. It can improve students' final score and teaching satisfaction.

Keywords. Formative evaluation, doctor-patient communication skills, online teaching, application value

1. Introduction

This paper combines formative evaluation with the online teaching of Doctor-patient Communication Skills to study the application and effect of formative evaluation in the online teaching of doctor-patient Communication Skills in the teaching process. In the whole teaching process to form a system of dynamic evaluation system, continuous use,

---

six minutes, phase contrast experiment method, using SPSS23.00 statistical analysis software, through the application of formative assessment to find enhance the teaching effect in the doctor-patient communication skills to learn online strategy, provide the basis for the teacher clear understanding of students learning process in time, Alleviate teachers' "teaching anxiety" and students' "learning panic" in online teaching. The teaching method of the course is optimized, the teaching effect is improved, and the students' communication skills and comprehensive quality are improved.

The formative evaluation method is to master students' learning situation at real time by tracking students' daily performance. Taking this as the referential basis, it will actively consummate the teaching mode and safeguard the efficiency of high-quality teaching [1]. Based on online learning platforms, formative evaluation is applied to the teaching of "Doctor-Patient Communication Skills". Through observing students, raising questions, observing their performance, their learning attitude, participation degree, homework acceptance, periodical mastery degree, skills training, and chapter test, monitoring and evaluating students' knowledge, skills, as well as the formation and improvement of their learning attitude, and feeding back the information to teachers and students in time, teaching methods will be adjusted in time. Meanwhile, the feasibility and existing problems of applying formative evaluation to the online teaching of "Doctor-Patient Communication Skills" will be studied, to find out strategies and methods of improving the teaching effect of this course by applying formative evaluation [2].

2. Materials and Methods

2.1 General Materials

Two classes of 2018 medical imaging technology major in our hospital were studied, including 124 students from Class 1 and 90 students from Class 2, totaling 214 students. 62 students from class 1 and 45 students from Class 2 were randomly selected. to from the experimental group, while the remaining students form the contrast group, with 107 members in each group. There are 50 male students and 57 female students in the contrast group (n=107), with the age threshold of 20-24 years old and the average age of (22.29±1.41) years old. There are 60 male students and 47 female students in the experimental group (n=107), with the age threshold of 19-24 years old and the average of (22.33±1.65) years old. After the contrast, the result shows that there is no significant difference ($P > 0.05$) among all the materials of all the students, so it is comparable.

2.2 Research Methods

All the 214 students are ensured to complete 24 class hours of online teaching activity of "Doctor-Patient Communication Skills", with unified teaching materials. Meanwhile, both groups are ensured to keep the same teaching schedule, and this teaching task is completed by the teachers in the same teaching and research section.

2.2.1 Regular teaching methods are conducted on the students of the contrast group.

Designated teachers are required to vividly display the teaching contents to students through multi-media devices. After finishing the course, paper test for students would

be performed without looking through any reference. Then, the test scores would be collected, to evaluate the effectiveness of teachers' teaching.

2.2.2 Based on the teaching methods of the contrast group, formative evaluation is performed on the students of the experimental group: including:

① to master the previously learned knowledge of students through presentation before class; ② to observe students' classroom performance, and make detailed records in their performance handbook; ③ to regularly conduct periodical tests on students, and set corresponding test questions with purpose; ④ to ask students to complete the questionnaire of self-evaluation, to summarize self-performance. Select computer network terminal or mobile APP of an online learning platform, and establish course resources. Then, students would enter the course learning through scanning QR code, and set different learning modules at different stages of course learning in line with the requirements of formative evaluation, including preview before class, course content, rushing to answer, discussion about knowledge, knowledge expansion, after-class test, after-class assignment, chapter test, and examination. For each stage, each chapter or module, students' learning situation and effects will be collected and analyzed before the next period of class, including the student number of finishing the tasks, positivity of rushing to answers, the number of taking part in free discussion, completion of after-class assignment, after-class test results, chapter test results, and exam results. Meanwhile, the data will be collected in time, and periodical analytical data of students' learning situation will be fed back to other teachers and students themselves before the next period of class, so that it is convenient for teachers to improve their teaching, and helps students to correct their learning methods and attitude. At the same time, students' feedback to teachers will be received, to realize two-way feedback system.

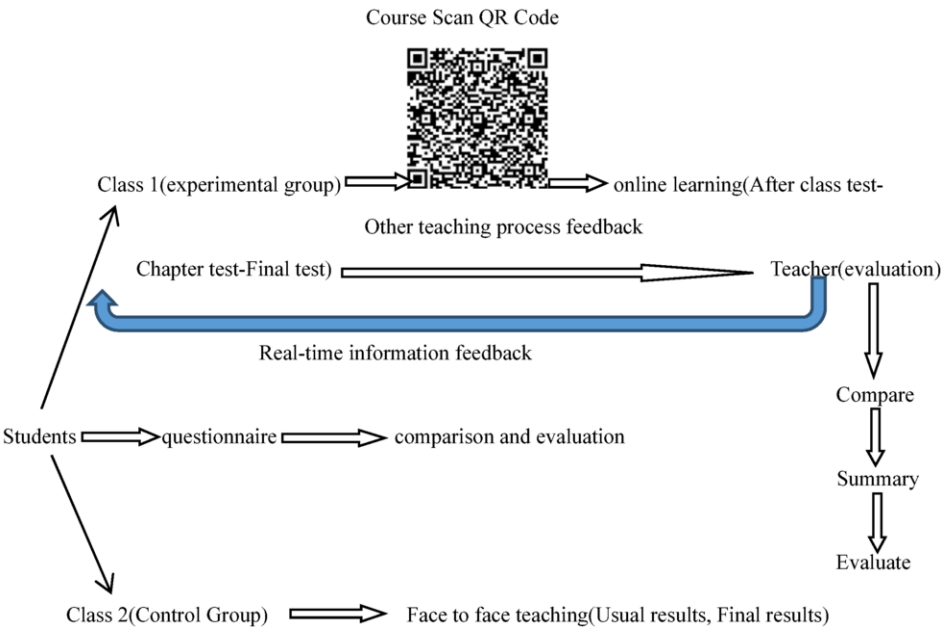The above steps can be represented in Figure 1.

Fig 1. Research method flow architecture diagram

2.3 Evaluation Contents and Methods

2.3.1 Analyze the online learning situation of the experimental group, including: online independent learning, online interaction, module completion, chapter test, and final exam result.

2.3.2 Compare the total score of final exams for students in both groups.

2.3.3 Through class questionnaire investigation, students' evaluation on online formative evaluation teaching and face-to-face teaching is compared.

2.3.4 Through all kinds of evaluation mechanisms for teachers' teaching ability, the evaluation on enhancing the teaching ability of teachers in both groups is compared.

2.4 Statistics Analysis

The experimental data is recorded in Excel 2021 form, and the statistical analysis software is SPSS23.00. Enumeration data is treated with X^2 test; while measurement data is treated with t test. Taking<0.05 as the judgment basis, the statistics in the group is analyzed.

3. Results

3.1 Comparison of Satisfaction about Both Groups

After systematic learning, the satisfaction level to teaching methods of students in the experimental group is obviously better than that of the contrast group, so it features outstanding statistical significance($P<0.05$), which is shown in Table 1. The passing rate of theoretical knowledge for students in the experimental group is 100.00%, while there are 5 students in the contrast group with their scores lower than 60, so the passing rate of theoretical knowledge is 86.36%. The difference of these two sets of data is of statistical significance($P<0.05$).

Table 1 Analyze and Compare the Satisfaction of Students in Both Groups

Groups	Casenumber	Teaching method			Self-evaluation		
		Satisfied	Good	okay	satisfied	good	okay
The experimental group	107	80 (74.77)	27 (25.23)	0 (0.0)	90 (84.11)	17 (15.89)	0 (0.0)
The contrast group	107	70 (65.42)	30 (28.03)	7 (6.55)	75 (70.09)	27 (25.23)	5 (4.68)
t-value	-	-	-	7.236	-	-	5.119
P-value	-	-	-	0.007	-	-	0.023

3.2 Comparison of Theoretical Results of Both Groups

After comparing theoretical results, the result of experimental group is higher than that of the contrast group ($P<0.05$), which is shown in Table 2.

Table 2 Comparison of Theoretical Results of Both Groups   [n（$\bar{x} \pm s$）]

Group/item	n	Theoretical results
Experimental group	107	80.89±6.40
Contrast group	107	75.89±7.90
t	-	5.0870
P	-	0.0000

3.3 Measurement Results of CTDI-CV Scale for Students in Both Groups (see Table 3)

The index scores of basic quality, content skills, teaching method, teaching attitude, and teaching ability of members in the research group are all higher than those of referential group, P＜0.05, which is shown in Table 3.

Table 3   The Total CTDI-CV Score of Students of Both Groups and the Score of Different Dimensions   [n（$\bar{x} \pm s$）]

Item	Contrast group (n=107)	Experimental group (n=107)	P-value	t-value
Seek truth	27.15±5.78	28.13±6.52	0.05	0.3854
Open mind	30.42±8.03	37.50±6.47	<0.05	0.0000
Analytical ability	28.30±6.50	37.43±7.49	<0.05	0.0000
Systematical ability	30.21±6.20	30.07±6.52	0.05	0.9043
Self-confidence	24.15±4.29	37.30±5.37	<0.05	0.0000
Desire for knowledge	24.45±5.08	29.42±5.25	<0.05	0.0000
Cognitive maturity	28.15±8.04	35.50±7.03	<0.05	0.0000
Total score	192.26±38.11	235.30±40.07	<0.05	0.0000

3.4 Evaluation on Enhancing Teaching Ability of Personnel in Both Groups

The CTDI-CV score of the students in the research group is significantly higher than that of the referential group. And the scores for indicators, like seeking truth, opening mind, analyzing ability, systematical ability, confidence and desire for knowledge, and recognition maturity, for the members in the research group are all higher than those of the referential group, with P＜0.05, seen in Table 4.

Table 4 Comparison for the Improvement of Teachers' Teaching Ability in Both Groups [n（$\bar{x} \pm s$）]

group/item	The experimental group(n=107)	The contrast group(n=107)	t	P
Basic quality	27.12±5.80	22.22±4.21	7.072	0.0000
Content skills	43.69±8.30	32.80±6.20	8.152	0.000
Teaching methods	15.01±1.79	13.18±2.80	4.4395	0.0000
Teaching attitude	17.40±3.30	15.62±2.30	3.5677	0.0005
Teaching ability	103.22±17.20	97.60±12.50	2.1309	0.0350

4. Analysis and Discussion

In traditional educational methods, due to the influence of exam-oriented education, students only pay attention to final exam results. And when evaluating the teaching quality, students' examination scores are regarded as the only evaluation standard [3]. However, the formative evaluation focuses on students' performance in their learning process, which can actively lead teachers to effectively adjust their teaching methods through students' actual learning. Therefore, a good atmosphere of "benefiting teachers and students as a whole" would be created for students [4]. This evaluation method can not only improve some weaknesses in teaching, but also inspire students' positivity of learning. When teaching "Doctor-Patient Communication Skills", the educational function of formative evaluation should be given full play to, to break through the single assessment model, thus leading students to feel the enjoyment of learning to the full. This method can help students conduct active and in-depth research about the ever-changing "Doctor-Patient Communication Skills", and help them solve some real problems during the process of learning "Doctor-Patient Communication Skills" with other students, to avoid students being over-stressed for attaching too much attention to the test scores and inhibiting their learning effects [5]. Formative evaluation was first put forward by Professor Scriven, an educational expert of Harvard University, in his works of "Teaching Education" in 1967, which was then introduced to the teaching area by B. S. Bloom from Chicago University. With continuous perfection, the teaching strategies for mastering learning was put forward [6]. Its purpose is to promote students' development, to evaluate students' feelings, attitudes, ability, and strategy performed in the process of learning, and to feed back the results to teachers and students in time. In this way, it will promote the adjustment and improvement of both parties of teaching, and help form a more effective teaching process [7]. The research dissertations about formative evaluation in medical education first appeared on journals in 1994. With constant development of formative evaluation, its application in medical education has been greatly increased. Since 2014, the number of published dissertations has been increased sharply, arousing the concern of more and more researchers, but with uneven progress [8]. Doctor-patient communication is one of the compulsory subjects of humanistic quality education of medical students, and good communication skill is a key method to reduce the rate of doctor-patient disputes. However, colleges and universities in China now have not attached great importance to the humanistic quality education of medical students, so there are few projects for medical colleges to effectively apply formative evaluation to the humanistic quality education [9]. According to the "Opinions on strengthening the application and management of online open course construction in colleges and universities" published by The Ministry of Education in 2015 and the "Instruction on organizing and managing online teaching in regular institutions of higher education during the COVID-19 period from the office of COVID-19 working group" from the higher education office [2020] No. 2 document, "the internet +" education has become a significant method for the medical education in the new era[10]. Online teaching has become a mainstream teaching style now. At present, "Doctor-Patient Communication Skills" mainly combines traditional teaching method and online teaching method, so how to improve the quality of this course's online teaching quality has become a focus of all the teachers. Meanwhile, there are few research about the online teaching methods of this course both at home and abroad, and there are fewer researches of combining how to

make "the internet +" online teaching platform more intelligent, flexible, and real-time, with the systematic, process, and periodical test of formative evaluation.

The concept of formative evaluation was first put forward by G. F. Scriven in the course improvement in 1967, which was relative to summative evaluation, to make educators examine the science and rationality of the evaluation system. It transfers the evaluation system to teaching process, requiring teachers to evaluate their students at any time when performing teaching activities. Meanwhile, teachers are required to understand students' mastery of knowledge when performing the evaluation results, so as to give further play to students' learning ability and help them take a correct attitude. Formative evaluation is process evaluation in nature, which values students' mastery of course knowledge and skills during the teaching process, and concerns about students' long-term and overall development. Compared with summative evaluation, it features the following merits: first, it realizes comprehensiveness viewing from the evaluation process. Formative evaluation goes through the whole learning process of students. During students' learning process, students' psychological status and learning status can be understood through observation and communication, which can be regarded as the evaluation basis. In this way, students' learning can be mastered in an all-around way. Therefore, when carrying out teaching activities, it will be more targeted and directive, to arouse students' interest in English learning, and to avoid the asymmetric information about the teaching concept between teachers and students. Second, it realizes complete coverage of evaluation subjects. Formative evaluation includes students' self-evaluation, peer evaluation, teachers' evaluation, parents' evaluation, and contract evaluation. This new evaluation method does not take achievements as the evaluation standard and basis any more, but pays more attention to students' comprehensive ability, to dig out students' potential and fully carry out the "student-oriented" concept. Therefore, students will become "masters of evaluation" from "evaluated persons". Third, it realizes scientific viewing from the evaluation results. Formative evaluation can be applied to the whole stage of teaching activities, which can provide reliable teaching information to students and teachers, understand students' real situation, lead students to take an active part in teaching activities, promote students to establish their learning confidence, and radically change students' passive situation in learning. In other words, the evaluation results would be scientific and reasonable, and can be fed back to teaching activities as effective information in time.

With continuous innovation of teaching methods, the weaknesses of summative evaluation have been gradually presented out. However, in practice application, formative evaluation mainly centers on cultivating students, and the teaching focus is not limited on the scores of students, but the attitude and improvement of students in learning process. Meanwhile, formative evaluation attaches extremely importance to students' emotions, attitudes, and values. Through different perspectives and different dimensions, it would make comprehensive evaluation on students, to stand out the principal status of students. Meanwhile, in formative evaluation process, it would form a harmonious student-teacher relationship, to help teachers further find out students' learning requirements, and to carry out their teaching with more accurate targets. Through the analysis and research, we can see that when comparing students' satisfaction about teaching methods and self-evaluation, the satisfaction level of experimental group is higher than that of the contrast group, $P<0.05$; when comparing the theoretical results, the result of experimental group is higher than that of the contrast group ($P<0.05$); the teaching ability of members in experimental group is

better than that of the contrast group, P<0.05; and the CTDI-CV score of students in experimental group is obviously better than that of the contrast group, P<0.05. The reasons are as follows: through the application of formative evaluation, the strategies of improving online teaching effects of "Doctor-Patient Communication Skills" can be found out, to provide basis for teachers to make clear of students' learning process, and to relieve teachers' "teaching anxiety" and students' "fear of learning" in online teaching. Therefore, the teaching methods of this course will be optimized, the teaching effects will be enhanced, and students' communication skills and comprehensive quality will be improved. Meanwhile, formative evaluation attaches great importance to students' emotional attitude and values, which can carry out comprehensive evaluation on students from various perspectives and various dimensions. As a result, students' principal status will be explicit. Meanwhile, in formative evaluation process, it would form a harmonious student-teacher relationship, to help teachers further find out students' learning requirements, and to carry out their teaching with more accurate targets.

5. Conclusions and Reflection

5.1 Conclusions

When making use of formative evaluation in the process of teaching "Doctor-Patient Communication Skills", students can directly feedback their learning effects, and teachers can master students' learning during each stage at the first time, to give targeted after-class tutoring. Students can summarize their mastery of the course knowledge through formative evaluation, and directly feedback their problems of "not knowing how to learn or not comprehending the course" to teachers. At last, the total score of the final exam will be enhanced, students' learning independence will be improved, and teachers' teaching ability will be improved. The performance of formative evaluation can not only help students master the learning of "Doctor-Patient Communication Skills", but also consolidate students' professional skills, to achieve favorable teaching effect. Therefore, "Doctor-Patient Communication Skills" has favorable promotion value in clinical teaching. On the other hand, teachers can continuously optimize their teaching, lead students to carry out online independent learning, enhance their online teaching quality, improve their information teaching ability, and to achieve complementary growth between teachers and students. Meanwhile, this will offer references to online formative evaluation of this course and medical humanities education.

5.2 Reflection

In the application of clinical teaching, it is found out that the application of formative evaluation in online teaching requires favorable learning initiatives of students, so that they can feedback their learning to teachers in time. Meanwhile, teachers should possess high information teaching ability and the ability to analyze and deal with the materials. It also has high standards for the teaching facilities, requiring the regular operation of network teaching platforms, rich teaching resources, as well as fast network operating speed of the teaching devices.

Acknowledgements

References

[1] Li Baomin, Yu Qing, Yang Fenglei. The Impact of Blended Instruction on Students' Learning Performance: A Meta-Analysis Based on 106 Empirical Studies at Home and Abroad [J]. Open Education Research, 2022,28(01):75-84.
[2] Fang Chengyu. Dormant Subject: The Subjectivity Dilemma and Reflection of Online Teaching Based on a Survey of a Middle School in the County [J]. Open Education Research, 2022,28(01):85-92.
[3] Wang Chao, Zhao Hui, Xue Xiaoxuan, Yang Ling, Wang Zhaoxin, Yuan Shuqi, Liu Yan, Li Wenhua, Lu Zheng. Application of BOPPPS+ PBL Teaching Mode in Online Teaching of Ultrasonic Diagnostics During COVID-19 Epidemic [J]. Anhui Medical and Pharmaceutical Journal, 2022,26(02):421-424.
[4] Cheng Qian, Yang Min, Guo Zhijun, Zheng Xubing. Study on the Status Quo of Online Teaching Quality of Ideological and Political Theory Courses and Its Improvement Countermeasures [J]. Contemporary Vocational Education, 2022(01):89-95.
[5] Sun Yongqiang. Practical Thinking and Application of Large-Scale Online Teaching in Local Colleges and Universities—Based on Questionnaire Survey of HNU in Jiangsu [J]. Teaching of Forestry Region, 2022(01):30-33.
[6] Zuo Xin. Research on Task-Driven Teaching Mode of Online Teaching [J]. Journalof Educational Institute of Jilin Province, 2022,38(01):19-22.
[7] Zhuang Fang, Tu Zhen. Design and Implementation of Multi-Terminal Interoperability Online Teaching Platform Based on MyBatis Framework [J]. Techniques of Automation and Applications, 2022,41(01):182-185.
[8] Qiao Huijuan. Exploration and Practice of Online Teaching in Colleges and Universities—Taking the Courses in Law as an Example [J]. Industrial & Science Tribune, 2022,21(02):142-143.
[9] Jia Jiyou, Le Huixiao, Li Zhuorun, He Guiying, Zhang Haiyan. Artificial Intelligence Helps the Balanced Development of Education—Taking the Effective Tutoring of a Personalized Online Instruction System for Migrant Children as an Example [J]. China Educational Technology, 2022(01):42-49.
[10] Fang Leyou. The Survey and Analysis of Online Teaching of 20 World-Class Universities[J]. Library Science Research & Work, 2022(01):14-22.

A Survey on the Status Quo of Dormitory Equally Shared Fee at Universities: A Case Study of Xiangnan University

Ling HE [a] and Yu LIU [b,1]

[a] *School of Educational Science and Law, Xiangnan University, 423000, Chenzhou, Hunan Province, China*

[b] *School of Public Health, Xiangnan University, 423000, Chenzhou, Hunan Province, China*

Abstract. Dormitory equally shared fee is the expense collected from all dormitory members voluntarily and used for dormitory group activities or communal purposes. Investigating the average level, sources, and the spending structure of the dormitory equally shared fee opens up a new pathway to understanding the dormitory life of college students and the status quo of collaboration between the school and dormitory in talent fostering. A questionnaire survey was administered to 242 dormitories at Xiangnan University. Some individuals were picked for case interviews. The prevalence, amount, source, spending structure and the influence factors of the dormitory equally shared fee were analyzed. The research findings provide clues for guiding college students' dormitory life, dormitory management, and collaboration between the school and dormitory in talent fostering.

Keywords. College students, dormitory equally shared fee, dormitory culture

1. Problem statement

For a long time, China's college dormitories were mostly welfare accommodations. "Everything seemed to be offered free, including electricity and water, cleaning tools, dormitory telephones, accommodation, or even personal supplies, such as lunch boxes, water bottles, and washing powder." [1] China has successfully established a market economy and continuously expanded the higher education. After entering the 21st century, "welfare accommodation" offered at colleges and universities has receded into history, giving way to market-oriented accommodation that collects fees from students. "As far as the American colleges and universities are concerned, dormitories are similar to classrooms as they are both parts of the school environment and affect students' learning and development." [2] Carla Yanni (2019) believed that "dormitory is a place of exclusiveness, and more importantly, a place of friendship." [3] Dormitory life performs an educational function to a non-negligible degree. "Apart from classrooms

and labs, residence, as an informal extracurricular learning environment, can also greatly promote students' success." [4] Satisfactory inputs are needed to build satisfactory dormitories. "By providing the right learning environment and a stimulating and stable social experience, good quality, affordable and well-managed housing can contribute significantly to students' overall educational experience." [5] In recent years, Chinese colleges and universities have practiced the philosophy of "collaboration between the school and dormitory as part of the talent fostering system." [6] As the college accommodations improve, the number of students living in one dormitory decreases. The students now have more individualized accommodation choices but fewer opportunities for group activities. The contradiction between "yearning for collective involvement and priority of individuality" seems to be worsening. Collective activities and life at school need financial support. To make up for the funding gaps, the colleges and universities invest continuously in dormitory buildings, facilities, and culture, which promotes the collaboration between the school and dormitories in talent fostering, directly and indirectly. But, given the diversity of the communal life of dormitories, a centralized and highly efficient investment in this area is hardly possible. Single funding channel is not conducive to supporting the richer collective life and the interpersonal communication of college students. When it comes to college students' financial contributions to the communal life of the dormitory, we define the concept of the dormitory equally shared fee as follows: It is a sum paid voluntarily by all dormitory members, apart from the accommodation fees, and used for dormitory group activities or communal purposes. As its definition entails, the dormitory equally shared fee is college students' voluntary investment in the collective life of dormitory, filling the financial gaps left by the school for the communal life on the dormitory level. However, the dormitory equally shared fee system has not aroused due attention at all levels, outside or inside the school. Compared with other living expenses, we still know little about the dormitory equally shared fee that has become a part of college students' life. This paper dealt with the dormitory equally shared fee system practiced at Chinese colleges and universities. On-site inspection, interviews and questionnaire survey were conducted at Xiangnan University, a provincial-level undergraduate college in Hunan, from February to March, 2022. A case study was performed to investigate the status quo of the dormitory equally shared fee at Xiangnan University.

2. Samples and methodology

The survey was targeted at the dormitories of full-time undergraduate students. Thirty males and forty females dormitories were randomly selected for each grade. A total of 280 copies of the questionnaire were distributed, and 242 copies were valid. The valid rate was 86.4%. All statistical analyses were conducted using the SPSS 20.0 software. The composition of samples with different features is shown in table 1.

Table 1. Distribution of dormitory sample features

Samples		Number (242)	Percentage(%)
Grade	Freshman	41	16.9
	Sophomore	81	33.5
	Junior year	74	30.6
	Senior year	46	19
Gender	Male	106	43.8
	Female	136	56.2
Major	Normal university student	137	56.6
	Non-normal university student	105	43.4
Discipline	Humanities and social sciences	71	29.3
	Science and engineering	98	40.5
	Arts and sports	73	30.2

3. Survey results and analysis

The dormitory is an important stage in college students' life. As the number of college students increases and the credit system becomes more popular, some activities at the departmental and class levels have been transferred to dormitories. Chinese college students usually spend about 16 hours in dormitories, which accounts for 2/3 of their time in school [7]. Some have classified dormitories culture into the following types: chatting-based culture, card-based culture, nightlife-based culture, eating-based culture, karaoke-based culture, and online game-based culture. Undoubtedly, students are eager to find a fairly warm harbor in a positive and pleasing dormitory culture, which also brings safety, friendship and other educational function. Investigating the average level, sources, and the spending structure of the dormitory equally shared fee opens up a new pathway to understanding the dormitory life and culture construction at colleges and universities.

3.1. The dormitory equally shared fee scheme is prevalent among college students

It's easy to find from table 2 that dormitory equally shared fee scheme has become commonplace. However, 14.9% of the respondents said that they had never paid such a fee. The truth may be that these students are less familiar with such a small fee and what it means. Besides, these students may be less concerned with public life at colleges. Nearly one-half (48.3%) of the respondents had paid this fee once or twice; 26.1% had paid this fee three or four times. These respondents collectively accounted for 74.4%. At most dormitories, a certain amount of the dormitory equally shared fee is paid by dormitory members in advance to the designated person (usually the dormitory head), in a similar way as they pay the class fee. If the actual amount spent exceeds the amount paid in advance, the students will fill the financial gaps later. The major difference between the class fee and the dormitory equally shared fee is that the former is paid once every semester or academic year, while the latter may be collected several times, each for varying amounts.

Table 2. Distribution of the number of payments per semester

The number of payments	Number	Percentage(%)
0	36	14.9
1~2	117	48.3
3~4	63	26.1
5~	26	10.7
Total	242	100

3.2. The total amount of the dormitory equally shared fee is generally low

In table 3, the amount of 200-299 yuan per person per semester had the highest frequency. Dormitories with this amount of dormitory equally shared fee accounted for 40.5% of all samples. Dormitories with the amount below 300 yuan accounted for 58.7%. The cumulative proportion of dormitories with the amount below 400 yuan was 80.6%. The cumulative proportion of dormitories with the amount below 500 yuan was 95.5%. Those with an amount above 500 yuan accounted for only 4.6%. Another survey showed that the median average monthly expense was 630 yuan among college students in 2005 [5]. It rose to 1516 yuan in 2020, a 2.4-fold increase than 15 years before. Suppose that each semester lasts four months, and the total living expense for a college student per semester totals 6064 yuan. During the current survey, the largest amount of dormitory equally shared fee per person per semester was 650 yuan, and the smallest amount was 155 yuan. The average was 298.43 yuan, accounting for 4.92% of the total cost of living per semester. The above results showed that the amount of dormitory equally shared fee paid by Chinese college students is generally low.

As analyzed above, the dormitory equally shared fee is insufficient to pay for consumables. Some consumables cannot be replenished timely, including bottled water, brooms, hand sanitizer, toilet detergent, toilet paper, and disposable cups. For example, we interviewed a male dormitory, and the dormitory members warmly received us. But much to their embarrassment, the head of the dormitory could not find a disposable cup to give me some water to drink. There seems to be a widespread shortage of public supplies at the dormitories. In some dormitories, the consumables are replenished by specific members solely at their own expense. There are also dormitory members (typically males) who uses other members' belongings at random or without getting permission beforehand. Such behaviors of microaggression harm the dormitory interpersonal relationship. Further, a tense interpersonal relationship will "indirectly increase the risk of smartphone addiction among college students by increasing their social anxiety and the need for affiliation"[8]. In another interview, we learned that every member of one dormitory paid 650 yuan and above in one semester. Many students have to queue to use the few public washing machines . So the four members of this dormitory finally decided to buy some household appliances (e.g., washing machine and dryer), dividing the total sum equally. But this case was only an exception. Most dormitories chose the public laundry service that cost 5 yuan per bucket. Professor Cheng Jieming, the senior consultant for the President of the University of Hong Kong, defines a college dormitory as "a place for young intellectuals to learn how to live together." [9] "In the United States, a college dormitory is not only a place to live but also a classroom and a place to foster talents." [10] A college dormitory can perform many other functions in light of these newly-recognized functions, with a rest place being only one of them. At colleges and universities, a dormitory is the smallest

unit of organization, a place for students' living, learning, and entertainment. For the dormitory to fulfill more functions, the dormitory members have to pay more to add to the dormitory equally shared fee. If the total amount of the dormitory equally shared fee is too small, the dormitory members will have too little to spend on collective cultural and other activities.

Table 3. Distribution of the amount of dormitory equally shared fee

Dormitory shared fees for each semester(RMB,yuan)	Number	Percentage (%)
＜200	44	18.2
200~	98	40.5
300~	53	21.9
400~	36	14.9
500~	7	2.9
600~	4	1.7

3.3. The expense to meet the basic survival needs accounts for the greater part of dormitory equally shared fee

As shown by the spending structure of the dormitory equally shared fee in table 4, the electricity and water fees, fees for dining together, and daily chemical products accounted for a higher proportion, which was 25.8%, 21.0% and 18.2%, respectively. These three expense items accounted for 65% collectively, indicating the predominance of expenses to meet basic survival needs.

Table 4. Spending structure of dormitory equally shared fee

Expenditure item	Frequency	Percentage (%)
Dining together	105	21.0
Tourism	8	1.6
Daily chemical products	91	18.2
Electricity and water	129	25.8
Communications and home appliances	42	8.4
Newspaper and periodicals	19	3.8
Medicine	4	0.8
Chess and cards	26	5.2
Balls and other fitness equipment	16	3.2
Decorations	53	10.6
Other	7	1.4
Total	500	100

By contrast, the collective proportion of expenses spent on tourism, balls and other fitness equipment, newspaper and periodicals fell short of 10%, indicating lower entertainment and spiritual needs. The reason is two-fold. First, the undergraduate students are less financially well-off. They have to cover their basic needs first with limited money. Second, the undergraduate students do not take the collective life seriously enough, devoting too little time and money to it. A weak sense of community is one common criticism directed at current college students. According to our interviews, members of a few dormitories have found part-time jobs outside the school

and do not live in the dormitories often. Others also live off campus with their girlfriends or boyfriends. Maybe it is time to advocate a collective life at colleges and universities in an era that prioritizes individuality. College students should be encouraged to return to their dormitories more often. College students can warm up the dormitory atmosphere by participating in collective activities, which will help dispel their sense of loneliness and develop interpersonal communication competence.

3.4. The sources of the dormitory equally shared fee comes are limited

We can know from table 5 that the sources of the dormitory public fund are limited. Among all dormitories surveyed on the question (a multiple-choice question) regarding the funding sources, 70.1% of the dormitories chose "payment by dormitory members"; 27.0% of the dormitories chose work-study program, for example, revenue from selling scrap; 2.5% of the dormitories chose other(for example, the cash bonus 200 yuan of the "Outstanding Dormitory Award"). Some students told us during the interviews that despite the revenue from selling scrap, the majority was funded by payments from the dormitory members. This is considered a manifestation of the widespread phenomenon that most Chinese college students are financially reliant upon their parents. According to our interview with one male dormitory, the members often tend to play cards and chest together in the dormitory during their spare time. Most of money earned during the game directly went to the public fund that would be spent on dining together. The members of this dormitory said that all members would benefit from this mode of public funding, which gives them a chance to learn social skills and solves the money problem.

Table 5. Distribution of the sources of dormitory equally shared fee

Sources	Frequency	Percentage(%)
Members pay	195	70.1
Work-study programs	75	27.0
Sponsorship	1	0.4
Other	7	2.5
Total	278	100

3.5. The respondents are generally satisfied with the dormitory equally shared fee system

Every college dormitory in China has a head responsible for the collection and spending of the dormitory equally shared fee. The dormitory equally shared fee system is so far considered diplomatic and transparent. According to our survey, most of the head of the dormitory kept clear records of expenses and managed the fees properly. As shown in table 6, 26.86% of the respondents were very satisfied with the dormitory equally shared fee system; 45.87% of the respondents were fairly satisfied. These two fractions of respondents accounted for 72.73% collectively, indicating a high satisfaction degree. However, another principle may hold true here: One's satisfaction with an object is inversely proportional to their expectations. From this perspective, Chinese college students still have low awareness and ability of self-governance. They have little expectation about the dormitory equally shared fee system. This system has remained barely active for a long time. In fact, most students who have once benefited from this small amount of fund will agree that it enriches their communal life, opening

up a new world of collective living. The dormitory equally shared fee that enables a more active communal life has brought them joy and new knowledge, leaving an imprint on their college life.

Table 6. Distribution of the degree of satisfaction with the dormitory equally shared fee system

Satisfaction	Frequency	Percentage (%)
Very satisfied	65	26.86
Satisfied	111	45.87
Neutral	56	23.14
Unsatisfied	7	2.89
Very unsatisfied	3	1.24
Total	242	100.00

3.6. Influence factors of the amount of dormitory equally shared fee

At Xiangnan University, an undergraduate student dormitory usually has four students (such dormitories account for 99.17% of all surveyed). As shown in table 7, the amount of dormitory equally shared fee was 316.60 per person per semester in the male dormitory vs. 284.05 yuan in the female dormitory. The difference was 32.55 yuan, which was statistically significant. Hence, gender has an impact on the average amount of dormitory equally shared fee. So what is the reason for such a difference? The amount of the dormitory equally shared fee spent on electricity and water and dining together accounted for 25.8% and 21.0%, respectively. These two expense items accounted for 46.8% collectively (table 4). Our survey showed that the difference in the amount of money spent on dining together contributes most significantly to the total difference. The female and male students did not differ considerably in the frequency of dining together. However, the total cost per dining out differed among the genders, especially the expense of alcohol. Besides, the number of guests of the opposite sex invited by the dormitory members was significantly higher for males than females. The second greatest source of difference is the amount of expense on electricity. The electricity price for the dormitories surveyed is 0.604 yuan per kilowatt-hour; the water price is 3.41 yuan per ton; the price of hot water is 27 yuan per ton. We found that the electricity and water expenses were generally higher in male dormitories than in female dormitories. This result demonstrates the prevalence of the online game-based culture and online chatting-based culture in college dormitories. The online chatting-based culture exists extensively in some female dormitories. However, the online game-based culture is more common and deeply rooted in male dormitories. A greater proportion of male students stay up late playing online games or on their smartphones than female students. The female students generally lead a more regular life than their male counterparts. These facts explain the higher electricity expense in male dormitories than in female dormitories. According to our statistics, the type of major (teaching or non-teaching majors), type of discipline (Humanities and Social sciences, Science and Engineering, arts and sports), and grade (the first, second, third, and fourth grades) had no significant impact on the amount of dormitory equally shared fee. As shown by our results, the intensity and frequency of needs for communal living, learning and entertainment activities funded by the dormitory equally shared fee did not vary by the type of major, discipline and grade. Although the spending structure varied somewhat for students of different grades, there is not much difference in the total amount of the dormitory equally shared fee.

Table 7. Comparison of the average dormitory equally shared fee

Samples		number (242)	Amount of dormitory equally shared fee ($\bar{x} \pm s$)	F/t	P
Grade	Freshman	41	296.46±100.71	0.180	0.910
	Sophomore	81	298.16±108.94		
	Junior year	74	293.45±104.79		
	Senior year	46	308.04±114.86		
Gender	Male	106	316.60±108.79	2.372	0.019*
	Female	136	284.05±103.66		
Major	Normal university student	137	289.96±105.73	1.389	0.166
	Non-normal university student	105	309.20±108.05		
Discipline	Humanities and social sciences	71	298.24±104.93	0.102	0.903
	Science and engineering	98	301.54±114.79		
	Arts and sports	73	294.04±98.97		

Note: * represents $P<0.05$.

4. Summary and suggestions

The public spirit is waning among Chinese college students, which is accompanied by the gradual popularization of the elective course system and course credit system, etc. All these changes have increased freedom of college students. Notably, there is an increasing number of dormitories where students of different grades and majors live together. In that case, there is little time for communal life for the dormitory members, and the dormitory equally shared fee system is hardly of any use. Along with the popularization of higher education in China, there are more boarders living on campus. In this context, Chinese colleges and universities have gradually renewed their perceptions of the functions of college dormitories. A college dormitory is more than a place to sleep in. There has been a growing recognition of the teaching philosophy that highlights the ubiquity of education. This philosophy has seeped down into student affairs management at Chinese colleges and universities. The implicit educational value of college dormitories has drawn increasing attention. With government funding and utilizing the market economy mechanism, Chinese colleges and universities have stepped up investments in dormitory infrastructure and dormitory management team. In recent years, guidance has been offered to college students, especially freshmen, to boost their awareness of the educational function of dormitories. Some progress has been made in dormitory culture construction. The survey shows that both schools and students should pay more attention to further optimize the collection and expenditure mechanism of dormitory sharing fee, and strengthen the cooperation between schools and dormitories in talent training. Based on our survey findings, we propose the following suggestions.

Interpersonal communications among dormitory members should be encouraged to awaken the public spirit and students' passion for communal life. The change in mentality should be further translated into actions. For example, the students are expected to participate in more beneficial activities along with other dormitory members and contribute more to the dormitory collective funding. After reaching a consensus through negotiations, the dormitory members should organize more collective activities and, to fund these activities, increase the contribution to the public funding as appropriate. Due to the flexibility and contingency of the dormitory equally shared fee, it is preferable not to set a fixed budget beforehand. Instead, the payments can be collected in smaller amounts each time, for several times. A lump-sum payment is disfavored. The spending of the dormitory equally shared fee should be based on the principles of frugality and democracy. Attention should be given to avoid adding to the economic burden for college students. Accounting is necessary at the end of the semester.

As for the dormitory management, counselors and head teachers with a good sense of responsibility should be appointed. They should pay regular visits to dormitories to help students cope with any problems in living, learning, psychology, and interpersonal interactions. The colleges and universities should implement loose policies regarding the collection and spending of dormitory equally shared fee. The students should be given a chance for self-governance and free from excessive interference from the school. Besides, colleges and universities should organize various activities to guide the establishment of a flexible and well-functioning adaption mechanism on the dormitory level. The ultimate goals are to raise students' self-governance ability and bring into full play the educational function of dormitory life.

Acknowledgements

References

[1] Taiqin Wang. From Dormitory to Apartment: The Change of Educational Idea of Higher Education in China from the Perspective of Accommodation Form[J]. Journal of China University of Political Science and Law, 2019(4):112-208.

[2] Bo Xu. The Research of American Residential Education Plan[J].Science of University Education.2016(3):112-117.

[3] Carla Yanni. Living on Campus: An Architectural History of the American Dormitory. University of Minnesota Press, 2019:37

[4] Samichelle, Ballesteros Marina, Garciagonzalez Sarah. Privacy, Personalization, and Presentation in Bedroom Spaces: Examining the Role of Residence Halls for Undergraduate Students. Journal of College and University Student Housing. 2021, 47(2):84-99.

[5] Sarah Jones, Martin Blakey. Student Accommodation: The Facts. HEPI Analytical Report 2. Higher Education Policy Institute, 2020: 62.

[6] Yang Cao, Zu-wang Chu, Chen-chen Lin. House collaboration: Practice and Inspiration of Residential community in American Universities－A case study of University of Wisconsin-Madison [J]. Research on ideological education,2021,(12):155-159.

[7] Huiying Mi. On the Cultural Construction of College Students' dormitory [J]. Chinese Adult Education,2006,(8):50-51.

[8] Qingtong GUO, Mingxue XU. The Relationship Between University Students' Dormitory Relationship Disturbance and Mobile Phone Addiction: A Sequential Mediation Model and Gender Differences[J].Psychology and behavior research, 2021(5):650-656.

[9] Jieming Cheng. I and College Dormitory [J]. Shanghai Education, 2006, (3):35.

[10] Bo Xu, Fangfei Jiang. The Generation Logic of dormitory education Function in American college and enlightenment to Modern Chinese Academy[J]. Jiangsu Higher Education,2021(3):86-92.

Re-Engineering Approach on Human Resources Management Practices (HRMP) Towards Chinese Teaching System in Nursing Programs

Juan WANG [1], Qiang LI [2] and Min CHEN[1] [3]

[1] Human Resource Department, Qiqihar Medical University, Qiqihar, China
[2] School of Nursing, Qiqihar Medical University, Qiqihar, China
[3] Department of Admission and Employment, Qiqihar Medical University, Qiqihar, China

Abstract. The purpose of this study is to discuss the re-engineering strategies on human resource management practices in China's higher education system, particularly in Nursing institutes. The Lecturers in Chinese nursing higher education institutions have limited deliveries (sessions) on Human Resources Management (HRM) module, thus the nurses have a challenge while dealing with patients. Through this research, it has been highlighted with evidence to teach students practical HRM skills has numerous benefits and so that Chinese nursing students can match their academic understanding with their practical experience. By reviving this practice, it becomes a process of re-engineering in Chinese teaching systems. This applied research had 91 respondents   collected through primary data. SPSS tool is used to analyse these datasets. ANOVA and Measurement model analysis were done based on the data collected.

Keywords. Human resource management, Practical teaching system, Experiential Learning, Staff development, nursing, HRM practice, teaching system

1. Introduction

The purpose of this study is to revive or retune the approaches to comprehend the value of HRM in the practical teaching system in order to help Chinese nursing students learn more. This re-engineering process in primary data gathering will yield quantitative output, which has been analysed using SPSS (Statistical Package for Social Science) tool version 26.0. China has 4.71 million registered nurses in 2021 [1]. Beijing University in China offers 85 clinical master's degrees, and the Chinese university offers regal practical training to nursing students [2]. The teachers in these institutions

needs to motivate the students to participate in practical activities to understand the different challenges and opportunities in the HRM process [3].

Students learn through observing HRM operations in real time and gaining practical information on how to manage human resources in health care to improve the quality of diagnostic and treatment services [4]. Nurses need HRM practical knowledge to understand and apply the ethical and legal norms of the healthcare sector in real-time practise [5]

2. Research Objectives

RO_1 - To comprehend the importance of a practical teaching system through re-engineering approach in the nursing undergraduate programme on human resource management practices

RO_2 - To evaluate the role of a practical teaching system in improving the human resource management practice of nurses

RO_3 - To identify factors affecting High Commitment Human Resources Management Practices in Chinese teaching system in Nursing programs

RO_4 - To produce the significant strategy to improve the practical teaching system in the nursing program

RO_5 – To propose a recommendation to overcome challenges in practical teaching system in China

3. Research Questions

RQ_1 – What is the importance of practical teaching system through re-engineering approach in the nursing undergraduate programme on human resource management practices?

RQ_2 – What is the role of a practical teaching system in improving the human resource management practice of nurses?

RQ_3 – What are the factors affecting High Commitment Human Resources Management Practices in Chinese teaching system in Nursing programs?

RQ_4 - How to improve the practical teaching system in the nursing program?

RQ_5 – How to overcome challenges in practical teaching system in China?

4. Literature Review

Re-engineering in Human resource management practises (HRMP) is fundamentally a process of rejuvenating the traditional practices with more focus to attain the effective output. There are a set of policies and procedures that are necessary for an organization's human resource routines to be performed and controlled. On the other hand, as mentioned by [6], a practical teaching method is considered "a learning method in which students are engaged in the learning process". Human Resources Management (HRM) skills have been studied in the light of composite or bundle approach, using different names as well as different practices. Largely, each bundle includes common HRM practices such as compensation, career development, staffing,

performance appraisal, training and development, and job design concerns with varying dimensions [5]. Now, this present study attempts to link these particular HRM practices and skills towards practical teaching system and process followed at nursing higher education institutions. Interestingly, prior studies identify these HRM skills related to staff development as priority among others [7]. Also, consistent with early findings, this present study looks into the impact of HRM skills within Chinese Nursing education institutions and the practical extent of these skills are adopted within the structures of higher education sector. Based on the extensive review of HRM skills literature and of existing HRM practices within higher education sectors in China, a research model (conceptual framework) is proposed (Fig.1) with Barron & Kenny type and propositions thereto are developed.
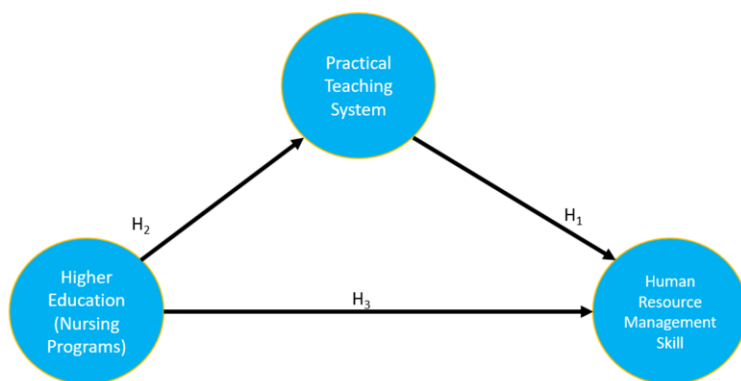
Figure 1 – Conceptual Framework based on Baron and Kenny's Method

Furthermore, human resource practices can be duly classified as "control" or "commitment" practices [8]. On one hand, practical teaching system seeks to increase efficiency. Thus, it is obvious that this approach concerns itself fundamentally with relationship between higher education institution, practical teaching system and HRM skills. Human beings are indeed the most difficult resources to manage, which brings about the relevance of High Commitment Human Resource Management; a Human Resource (HR) tool utilized to correctly direct and motivate humans to bring about objectivity in the attainment of goals in any organization

4.1 Hypothesis

H_1: There is a significant impact between practical teaching system and human resource management skills
H_2: There is a significant impact between higher education (nursing programs) and practical teaching system
H_3: There is a significant impact between higher education (nursing programs) and human resource management skills

5. Research Methodology

The study employed a quantitative methodology that included primary data collection along with reviewing secondary data. Measurement model was executed with collected data. Secondary data from online resources such as ResearchGate and ProQuest were used to compile the results. Due to non-availability of open-access articles in Scopus, Web of Science and CNKI authors were retrieving from ResearchGate and ProQuest. Based on the study objectives, all topics have been constructed to conduct a measurement model in order to answer the research question. As mentioned by [9], the advantages of measurement model are that it helps in relating the research context with real-time context and meets the research objectives. Moreover, descriptive design and inductive approach have been followed in this research. The primary research, on the other hand, was conducted through an online poll of 91 Chinese nursing school teachers. To perform the survey, ten questions on study aims and hypotheses were written, and the questionnaire was placed into Google Form. Interviews and surveys are the two most effective data collection methods in primary research, according to [10]. To get to the point answer of the respondents, all of the survey questions were closed-ended and multiple-choice questions were used. The survey's sample size is 91 people, and the respondents were picked using a random sampling technique. The sample size was calculated using the G-Power formula, which is one of the methods used for sample-size calculation process according to [8]. In this research, G-Power sample size calculation was based on Power analysis for one-sample T-test

6. Findings and Analysis

6.1 Descriptive test

Table 1: Descriptive test (Source: SPSS file)

		1. What is your age?	2. Do you have nursing skills?	3. Are you a teacher of a nursing undergraduate programme?	4. Do you think that nurses need training on human resource management practices (HRMP)?
N	Valid	91	91	91	91
	Missing	0	0	0	0
Mean		1.73	1.40	1.70	1.77	Mean
Median		1.00	1.00	1.00	3.00	Median
Mode		2	1	1	5	Mode
Std. Deviation		.587	.000	.000	.000	Std. Deviation

The above table represents demographic profile of respondents. This descriptive test has aided to comprehend the fundamental statistical values such as mean, median, mode and standard deviation. As a result of the mean value, it can be concluded that the majority of respondents are older; all respondents have nursing experience; the respondents are Chinese nursing school teachers, and that they agree that "nurses need training on human resource management methods.

6.2 Reliability and Validity

Table 2: Reliability and Validity (Source: SPSS file)

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Practical Teaching Systems	0.629	0.640	0.799	0.571
Higher Education System	0.680	0.685	0.742	0.591
Human Resources Management (HRM) Skills	0.669	0.670	0.820	0.603

Threshold for reliability is 0.6 [11]and above. Pertaining to this, all three constructs are having higher value that 0.6 Cronbach's Alpha thus they are reliable. Similarly, if the AVE is above 0.5, they are considered to be valid [11]. In the above table it could be found that AVE is above 0.5 thus they are valid.

6.3 Model Test Summary

Table 3: Model Test Summary (Source: SPSS file)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.717[a]	.350	.332	.770	.378	42.681	1	63	.000

Model Test indicates the significance value between each construct. In this research there are three constructs, and they are deemed to be significant as the Sig.F Change value is 0.000. This proves that the model is neutral. Moreover, this research has adopted Baron and Kenny model to determine the relationship between the constructs.

6.4 ANOVA

Table 4: ANOVA (Source: SPSS file)

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	34.000	1	34.000	42.681	.000[b]
	Residual	61.178	64	.884		
	Total	94.744	64			

ANOVA is the abbreviation of Analysis of Variance. This statistical test developed by Ronald Fisher in the year 1918, has been in use ever since. In simple terms, ANOVA indicates whether there are any statistical differences between the means of three or

more groups or latent variables. Here the mean square is .884 and significance is 0.000, which indicates that variables are significant.

6.5 Regression

Table 5: Regression (Source: SPSS file)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.222	.370		2.758	.000
	Nurses should have good HRM skill to have good team leading capability in health care	.581	.114	.677	6.743	.000

The regression test has helped to clarify the relationship between a dependent variable and the research's independent variable [12]. The dependent variable in this study is the Chinese nursing colleges' practical teaching system, while the independent variable is human resource management practise. "Sig value more than 0.05 suggests acceptance of the null hypothesis, whereas Sig value less than 0.05 indicates acceptance of the alternative hypothesis," according to [8]The Sig value in this regression test is 0.00, demonstrating that "there is a significant correlation between human resource management skill and practical teaching system [12]. "The R-value demonstrates the dependency of a dependent factor on a dependent factor," according to [13]. For instance, an R-value less than 0.3 represent a weak relationship and an R-value more than 0.5 indicates a strong relationship. In this case, the R square value is 0.381 which represents a direct relation between nursing teaching and HRM practice [9]. The R square value is 0.247 in the second regression test, and the Sig. value is 0.00. As a result, the alternative hypothesis is accepted in this situation, implying that Chinese nursing teachers have difficulty teaching HRM to nurses in the classroom. The R square value, on the other hand, implies a weak association between nursing practical teaching systems and theoretical content alignment with the practical environment [9].

6.6 Hypothesis Testing

Table 6: Hypothesis Testing (Source: SPSS file)

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values
Practical Teaching System -> HRM Skills	0.349	0.349	0.041	8.511	0.000
Higher Education System -> Practical Teaching System	0.129	0.128	0.031	4.229	0.000
Higher Education System -> HRM Skills	0.193	0.190	0.053	3.634	0.000

If p-value is less than 0.05, the construct is said to have positive relationship with the measured item. It is either p-value or t-statistics. For T-Statistics it has be more than 1.96. In this research all hypothesis has less than 0.05 p-value, thus the hypothesis is been proved.

7. Conclusion

Staff maintenance, development, relationships, team leadership, and training are some of the HRM methods used in China's practical teaching system [8]). This re-engineering approach by replacing the existing procedural process has befitted the entire mechanism. Staffing challenges, poor working conditions, funding, and "constant transfer of teachers, among other things" are some of the issues encountered in China's practical teaching system, according to the report [9]. HRM policy, rules, and regulations, as well as their impact on managing stars and the organization's work, are tickets for students in a realistic context [14]. As a result, rather than memorising HRM policies, the students learnt how to put those policies into reality [13]. In this research, the maximum responders have agreed that HRM practice and its practical experiment are very much needed to improve the HRM knowledge of the students and to implement that the school needs to employ teachers who have good experience and knowledge of HRM [15].

7.1 Limitation and Future Scope

Every research in social sciences and humanities has a scope of improvement as it is not fully accurate [15]. This respective research is no exception. The secondary data has been sourced from ResearchGate and ProQuest as addressed in earlier sections due to non-availability of open-access articles in high ranking journals. This could be a major setback or shortcoming of this research. Authors agree that Scopus or Web of Sciences or CNKI indexed articles should have also been considered. While this can be carried out by future researchers, it has been admitted that ResearchGate and ProQuest has stupendous and wide collection of research manuscripts. And more advanced statistical tools could have been more suitable to analyse and interpret the numerical facts.

7.2 Innovation and Contribution

Any re-engineering study is a noteworthy topic and particularly in the topic of human resource management whereby it evolves around Chinese higher education sector has numerous learning which can be implemented gradually. In the future, researchers might look at the various practical techniques used in Chinese education to increase students' HRM knowledge and skills. Furthermore, future research might look into the function of various technologies utilised in practical instruction to increase the quality of HRM practise in institutions. The practical implication of this research is, there could be a strategical policy in curriculum development for practical teaching system henceforth in Chinese Higher Education institutions [7]. This could blatantly improve the mechanism of teaching pedagogy and implementing HRM skills in the programs (particularly in nursing programs).

Theoretically, through this research there has been a conclusive framework that highlights the linkages between practical teaching system, higher education institutions and HRM skills. The conceptual framework with Baron and Kenny method illustrates how the linkages has been established. There has been nil or limited study pertaining to this, and thus this novelty would escalate the merits and outcomes of this research [9]. By testing the hypothesis, it still assures the potentiality and credibility of the model. Hence, this particular research's contribution could be prospective for any future

researches in Education and / or HRM and /or innovation. Based on the primary and secondary data analysis, it can be concluded that practical training is essential for providing proper guidance on human resource management in order to manage healthcare activity. The practical instruction provides nurses with practical guidance and expertise based on HRM practise in order to empower them to govern HRM and use the skill to manage patients, staff, and healthcare teams.

References

[1] J. E. Adaletey, V. Raju, and S. P. Phung, "Role of stakeholder in revenue mobilization to alleviate poverty in Ghana using E-governance mechanisms," Int. J. Innov. Technol. Explor. Eng., vol. 8, no. 2S, pp. 129–133, 2018.

[2] Z. Yizhou, Z. Simeng, and V. Raj, "A Discussion of the Application of Artificial Intelligence in the Management of Mass Media Censorship in Mainland China," ACM Int. Conf. Proceeding Ser., pp. 79–84, Aug. 2020, doi: 10.1145/3407703.3407719.

[3] S. P. Phung and V. Raju, "Framework assimilation in supply chain management: Exploratory study based on investigation," Int. J. Supply Chain Manag., vol. 8, no. 2, pp. 1090–1094, 2019.

[4] Z. Simeng, Z. Yizhou, and V. Raj, "Explore the Improvement of the Management of China's International Film Festivals Based on Artificial Intelligence," ACM Int. Conf. Proceeding Ser., pp. 63–67, Aug. 2020, doi: 10.1145/3407703.3407716.

[5] S. N. S. Mohd Adnan and R. Valliappan, "Communicating shared vision and leadership styles towards enhancing performance," Int. J. Product. Perform. Manag., vol. 68, no. 6, pp. 1042–1056, Jul. 2019, doi: 10.1108/IJPPM-05-2018-0183.

[6] M. R. H. Polas, V. Raju, S. M. Hossen, A. M. Karim, and M. I. Tabash, "Customer's revisit intention: Empirical evidence on Gen-Z from Bangladesh towards halal restaurants," J. Public Aff., 2020, doi: 10.1002/PA.2572.

[7] M. R. H. Polas, V. Raju, M. Muhibbullah, and M. I. Tabash, "Rural women characteristics and sustainable entrepreneurial intention: a road to economic growth in Bangladesh," J. Enterprising Communities, 2021, doi: 10.1108/JEC-10-2020-0183.

[8] V. Raju, "Implementing Flexible Systems in Doctoral Viva Defense Through Virtual Mechanism," Glob. J. Flex. Syst. Manag., vol. 22, no. 2, pp. 127–139, Jun. 2021, doi: 10.1007/S40171-021-00264-Y.

[9] V. Raju, W. Juan, S. Shrestha, A. Kalathinathan, and K. K. Ramachandran, "Role of big data analytics in belt and road initiative (BRI): Multivariate analysis with gaussian distribution of data," Front. Artif. Intell. Appl., vol. 341, pp. 169–177, Oct. 2021, doi: 10.3233/FAIA210245.

[10] M. Hmedan, V. R. K. Chetty, and S. P. Phung, "Malaysian tourism sector: Technical review on policies and regulations," Eurasian J. Anal. Chem., vol. 13, no. 6, pp. 114–120, 2018.

[11] J. F. Hair, C. M. Ringle, S. P. Gudergan, A. Fischer, C. Nitzl, and C. Menictas, "Partial least squares structural equation modeling-based discrete choice modeling: an illustration in modeling retailer choice," Bus. Res., vol. 12, no. 1, pp. 115–142, 2019, doi: 10.1007/s40685-018-0072-4.

[12] V. Raju and S. P. Phung, "Strategies to enhance supply chain management practices: Identifying the performance orientation," Int. J. Supply Chain Manag., vol. 8, no. 2, pp. 1079–1084, 2019.

[13] V. Raju and S. P. Phung, "Sustainability in performance management through supply chain management," Int. J. Supply Chain Manag., vol. 8, no. 2, pp. 1085–1089, 2019.

[14] A. Bhaumik, K. A. Law, Y. Xu, and V. Raju, "Empirical study on employee's psychological capital: Based on guangdong technology enterprises in China," Int. J. Control Autom., vol. 12, no. 5, pp. 88–98, Nov. 2019, doi: 10.37200/ijpr/v24i4/pr201116.

[15] S. U. A. Rana and V. Raju, "Factors influencing glass ceiling focus on women administration in higher education in Malaysia," Int. J. Eng. Adv. Technol., vol. 8, no. 6 Special Issue 3, pp. 461–468, Sep. 2019, doi: 10.35940/IJEAT.F1220.0986S319.

The Application of Interactive Case-Based Teaching Method in the Implementation of "International Law"

Yayi YAN, Wei ZHANG[1] and Jiaming ZHONG
Xiangnan University, Chenzhou City, Hunan Province, 423000, China

Abstract. Moral education in colleges and universities goes through the teaching of all the courses, which integrates into all the links of teaching and practice. In daily teaching, moral education is a kind of implicit education influencing in a imperceptible way. The teaching content of "International Law" includes profound moral education, which can effectively transfer from "ideological and political courses" to "ideological and political theories teaching in all courses". Therefore, interactive case-based teaching method is a good way to achieve ideological and political teaching in a "silent and soft" way. Through interactive case-based teaching, moral education can be penetrated into the lecturing of professional course knowledge and a series of activities, which can form the course teaching with the integration of "intellectual education" and "moral education", to integrate the values shaping, knowledge imparting and ability cultivation. In this way, the fundamental task of building morality and cultivating people will be fully implemented.

Key words. International Law; course teaching; interactive case-based teaching

1. Current Implementation of Ideological and Political Teaching in "International Law"

1.1 Lack of Coordination

At present, the teaching of international law lacks of systematic summary about the idea of international governance, and it has not systematically or comprehensively integrated into ideological and political teaching. Meanwhile, it has not formed the coordination with ideological and political education. The ideological and political teaching of "International Law" is a systematic work, so it is necessary to insist on the combination of teaching contents and ideological and political theories in all courses. It has to be advanced in an orderly way by combining the instruction of knowledge and the integration of ideological and political elements. Only with comprehensive consideration, strengthened coordination, and supportive advancement, can the teaching contents of "International Law" and ideological and political teaching achieve favorable comprehensive effects.

---

[1] Corresponding Author, Wei Zhang, Xiangnan University, Chenzhou City, Hunan Province, 423000, China; Email: 84514002@qq.com

1.2 Insufficient Extraction of Ideological and Political Elements

The extraction of ideological and political elements is to classify, induce, and summarize the ideological and political elements in the knowledge, and then integrate the elements at different levels. These elements are divided into primary ideological and political elements and secondary ideological and political elements. For instance, in terms of the basic principles of international law in the course of "International Law", the primary ideological and political elements   refers to national awareness, while national sense of honor, and the consciousness of maintaining national dignity and maintaining Chinese culture refers to secondary ideological and political elements (See Table 1).

Table 1 Two-Level Classification System of Ideological and Political Elements in the Course of "International Law"

No.	Knowledge points	Primary ideological and political elements	Secondary ideological and political elements
1	Basic principles of international law, source of international law, countries	National awareness	National sense of honor
			Consciousness of maintaining national dignity
			Consciousness of maintaining Chinese culture
2	Territorial law, law of the sea, international air law, outer space law	National sovereignty	Defending territorial integrity of our country, patriotism
			Heroism, national spirit
			The spirit of aviation, exploring spirit, craftsman's spirit
3	International human rights law, international environmental law	Values	National spirit
			Public ethics, moral sentiment
			Consciousness of ecological civilization
			Peace loving
4	Law of treaties, diplomatic and consular relations law, law of war, responsibility in international law, international dispute settlement	National spirit	Never forget the national humiliation, and cherish peace.
			Carry forward the national spirit of constantly striving to become stronger
			Patriotism
5	Private in international law	Values	National spirit
			Moral sentiment
			National sentiment
6	Law of international organizations	Confidence in political system	One of the five permanent members of the UN Security Council, reflecting the responsibility as a great power
			Chinese peacekeepers, heroism
			Peace loving

1.3 Poor Effect of Ideological and Political Teaching

In traditional teaching mode of international law, the ideological and political teaching is usually conducted through lecturing, resulting in the disconnection between professional knowledge and moral education. In this way, students are not highly involved in this activity, and the ideological and political teaching effect is poor. Therefore, to enhance the teaching effect of ideological and political theories in the course of "International Law", it is necessary to strengthen the integration, to achieve the ideological and political teaching in a "silent and soft" way through interactive case-based teaching method. Abundant ideological and political elements should be integrated into all the knowledge of "International Law" courses. First, the ideological and political contents in "International Law" should be flexible and diversified. Although the previous ideological and political teaching was conducted by lecturing, educators should master all kinds of teaching methods with the development of new media nowadays. The rich ideological and political elements should be integrated into the course through various cases, such as videos, pictures, and words, so that students will remain strong interest in learning, along with the unconscious inflection of ideological and political elements. Second, the ideological and political contents in "International Law" should present appropriate level of difficulty. Students' knowledge level and comprehension ability should be focused, and common knowledge principles and values should be well combined. When teaching the "International Law", the teaching content should be combined with the mainstream values, to promote and complement each other. Third, the ideological and political contents in "International Law" should comply with professional characteristics. "International Law" is the compulsory basic course of undergraduate students in the major of law, so the ideological and political theories in this course should be based on the professional teaching system and complete knowledge framework of law courses. Through fully integrating ideological and political contents into the value system of the major in law, it will develop the national identity, social responsibility, and moral cultivation of students in Law School, to cultivate the talents with international outlook in the new era for socialism.

2. Necessity of Interactive Case-based teaching Method in Ideological and Political Teaching of "International Law"

The legal thought of international law in modern China originates from traditional Chinese culture and traditional ideas, brewing an ideological system that manifests Chinese characteristics, safeguards Chinese interests, and promotes the world progress. Taking equality and independence as the bottom line and starting point, multi-civilization as the principle of communication, justice and effectiveness as the way of act, and mutual benefit as the final goal, it vividly reflects and actively guides the new pattern of international community state. All kinds of the features of the international law have provided favorable foundation to ideological and political teaching, so there is natural alignment between the teaching of international law and ideological and political education.

In recent years, case-based teaching has aroused the concern of numerous scholars. Case-based teaching, an interactive teaching method that teachers bring cases relating to the teaching contents into the teaching process, leads students to analyze the cases

and draw conclusions. [1]Current international affairs and news, some key international hot events in particular, are good teaching materials for the teaching of international law. These affairs and news cover the areas like diplomacy, military affairs, territory, and anti-terrorism, while these areas are the basic contents of the international law. When teaching international law, introducing current affairs and news as the case materials can stimulate students' learning interest, and can penetrate ideological and political education into the learning process of students. [2] Case-based teaching can form an effective closed cycle of knowledge learning, from independent inquiry, collaborative analysis, to introspection and internalization, which can lead students to complete given teaching targets through analysis, exploration, thinking, and discussion. The Chinese academic circles generally agree on the importance of the case teaching method in the ideological and political teaching of college courses. The academic community generally believes that the case teaching method is a practical method of ideological and political education. Some scholars believe that the case teaching method conforms to the laws of education and teaching and the characteristics of contemporary youth. Some scholars believe that by implementing this teaching method, it can improve students' interest in course learning, change students' prejudice against ideological and political theory courses, and optimize classroom teaching effects, which is beneficial to ideological and political theory. The further construction and development of theoretical courses. Therefore, the knowledge and emotions can be internalized, students' patriotism can be developed, the confidence in system can be insisted, and the process of learning the knowledge of international law and ideological and political education can be achieved at the same time.

3. Practice of Case-Based Teaching in Ideological and Political Teaching in the Course of "International Law"

3.1 Principles of Selecting Cases

In the case-based teaching model that targets at ideological and political education, it is a vital part to select appropriate cases. Through the practice and effects of case-based teaching, the following features should be emphasized when selecting cases.

(1) Typical. Typical cases in course teaching are the cases about hot social issues that students are interested in, which can not only offset students' contradictory feelings about explicit ideological and political education, but also largely carry out theoretical teaching for students. On the other hand, it can effectively give correct guidance to university students about public opinions.

(2) Targeted. It requires that the selected cases should comply with the teaching content of "International Law", and also well integrate the ideological and political teaching of the course. On one hand, the selection of cases is to serve related teaching contents, which can not get away from the topic.[3]On the other hand, it should not be difficult to comprehend the cases, and the selected cases should be set in line with students' interest, knowledge preparation, and psychological characteristics. During case-based teaching process of "International Law", and according to some objective conditions, like students' group characteristics (such as English level, major direction, and career

planning) and changes of current affairs, the content of cases should be determined appropriately, and the theme and duration of cases should be chosen, to meet the actual teaching needs. As a compulsory basic subject for undergraduate students in Law School, "International Law" should contain the cases complying with students' major characteristics. That is to say, the selected cases should enlighten the legal work that students may engage in the future, so that students are possessed with related knowledge accumulation and correct value direction when they engage in legal work in the future. Students differ in age, gender, and ideological situation, so even if they have similar conditions in all the aspects, they may have different ideas during their discussion due to different thinking directions or different comprehension.[4]Therefore, by seeking balance, teachers should find out the cases that most students can accept and can be integrated into their teaching according to different characteristics of student groups.

(3) Systematic. It requires that all the selected cases should make ideological and political teaching in the curriculum well-arranged and logical coherent. A single case in the whole case set should reflect a certain or some knowledge points in the "International Law", while the comprehensive cases can reflect the overall content of "International Law". [5]Not only all the parts of a single case possess systematic ideological and political teaching, but also all the teaching cases should have systematic ideological and political teaching, as well as among the cases. In specific, there should be ideological and political elements at different layers or different dimensions in a single case, to form appropriate sequence. There should be clear logical relationships between the elements at the same level, or between the primary and secondary ideological and political elements. What's more, there should be different ideological and political elements at different dimensions between cases. The integration of all the cases should contain the ideological and political elements of different levels and different aspects to the largest degree, so that the case set should be well arranged. The cases with similar themes or with different themes can complement each other.

(4) Timely. It requires that all the selected cases should reflect the features or properties of ideological and political teaching of the time, which should be the cases that can present the most advanced and best ideological and political teaching fruits. In order to fully step into students' learning, work, [6]and life from classes, books, or cases, the ideological and political education of "International Law" must select the cases that can keep up with the times and summarize new cases through continuous planning and arrangement. Through analyzing different legislation in different countries caused by different cultures and economic systems, teachers can help students insist on their confidence in laws and culture. For example, when illustrating international treaties, through analyzing the in-depth reasons of joining, not joining, or remaining related treaties, teachers can develop students' patriotism and patriotic spirit. By analyzing some hot issues like "the typical case of the Belt and Road Initiative", [7] teachers can lead students to correctly and objectively analyze international hot issues, establish correct world outlook and international concept, and understand the new situation and new challenges that China is facing in international environment. In this way,

students' sense of mission can be cultivated, leading students to combine professional learning and individual development with national development.

3.2 Case-Based Teaching Design

Case-based teaching is a teaching method based on cases(See Figure 1), whose essence is to raise a dilemma for education, without specific solutions. While teachers are designers and promoters in teaching, encouraging students to take an active part in discussion. Taking international hot issues and news events as teaching materials, and according to teaching goals, case-based teaching method combines teaching contents, lets students understand relative concepts or theoretical knowledge about international law, and cultivates students' ability of analyzing or solving problems about international law through interactive activities like discussion, debate, and questions.[8]It mainly conducts teaching surrounding case discussion and analysis, with students as the center of teaching activities, while teachers the guide and judge. This teaching method that connects theory with practice can stimulate students' enthusiasm in participation to the largest extent, so as to enhance teaching timeliness and effectiveness.

Figure 1 Case-based teaching method

4. Implementation of Case-Based Teaching

4.1 Case presentation

The core teaching material of case-based teaching is about the case, which is an experience process of presenting events, raising questions, and perceiving ideas through reading materials, so case presentation is the first step of successful ideological and political teaching, as well as a basic step to lay a foundation for teaching quality. Teachers should lead students to read materials, think about questions by linking current affairs, complete ideological understanding by combining ideological and political analysis, and provide ideas for group interaction. [9]Cases about international current affairs and news take international hot issues and news events as teaching materials, which focus on typical, targeted, systematic, and timely materials. With the combination of teaching contents and ideological and political elements, it can well match materials with and text contents, so that students can fully integrate into the context of teaching materials, truly feeling about impact and influences from events. [10]Then, students will carry out in-depth thinking through ideological and political elements. Case presentation can be divided into three steps. First, before the presentation, the teacher provides ideological and political theory that complies with teaching materials, and then introduces fascinating context or segment to arouse students' strong attention and careful study; secondly, during the presentation, the teacher is required to focus on important context of the case, [11]so that students can

form a focus and can rapidly understand the development, as well as the ideological and political elements of the case, thus stimulating students' enthusiasm in thinking and sense of participation. At last, after the presentation, review on key issues and important context of cases, to consolidate the learning about case knowledge and ideological and political elements. Meanwhile, teachers should raise questions, and leave room and time for students to think.

4.2 Group Interaction

Case presentation leads students to make primary recognition about materials by combining ideological and political elements and to form perceptual knowledge. While group interaction is a key link from perceptual knowledge to deep theoretical discussion, which is also an important process to make a qualitative leap about problem recognition by combining ideological and political elements. Group interaction can also be divided into three steps. First, raise questions about case presentation, and lead students to form the consciousness of problems by combining ideological and political elements within the scope of teaching content. However, teachers should not be overly involved in the process of shaping and thinking about problems, to form a set of problems. Second, students are required to form their groups freely, and from a group of exploring cases. During the process of forming groups, teachers should pay attention to group homogeneity (student members with different performance, grades, or personality, etc.).[12]Group members can complement each other in terms of way of thinking, logical analysis, and interests. At last, each group selects one or two students to make presentations, which can not only help students enhance their thinking in group discussion, but also help students hear about other group members' new problems, new thinking, and new ideas about cases. Therefore, students can form a more comprehensive and diversified comprehension towards ideological and political elements in the cases.

4.3 Knowledge and emotional internalization.

The last step and the final stepping stone of case-based teaching is knowledge and emotional internalization. After initial recognition and thorough discussion about cases, students should apply the ideas and thinking into real life, to achieve the effect of "internalizing in our hearts, and externalizing in our action, as well as the "soft and silent" educational effect about ideological and political education in the course. In specific, during the process of knowledge and emotional internalization, first, we should look back on cases, and strive to explore new perspectives and new ideas about cases, to achieve the effect of "understanding the present by reviewing the past". Second, expand cases. During this process, students should focus on analyzing cases by applying President Xi Jinping's theories about international governance, to achieve the effect of "drawing inferences about other cases from one instance". At last, combine with other cases and reflect on the present. Teachers should help students integrate President Xi Jinping's international governance theories into the analysis about international hot issues in life. No matter the classroom cases or book discussion, or the news, videos, or text browsing on mobile phones after class, teachers should guide students to consciously apply the ideological and political knowledge they have learned. Therefore, students can shape correct perspectives and habits of analyzing problems, which can bring sense of fulfillment and sense of happiness to their life.

5. Reflection on the Case-Based Teaching of Ideological and Political Education in the Course of "International Law"

If the case-based teaching of ideological and political education in the course of "International Law" can be fully applied in practice, it will be good for students to actively and positively learn the international law, as well as to be influenced by the "soft and silent" ideological and political education in the course.[13]Then, teachers will train students to consciously and actively integrate correct national consciousness, values, and patriotism into the process of analyzing and solving problems from the perspective of international law. The case-based teaching of ideological and political education in the course of "International Law" effectively integrates ideological and political work of school into professional courses, which can effectively improve the ideological and political teaching quality, as well as students' ideological and political accomplishment.

Acknowledgements

References

[1] Fan Ruxin, Zhang Chaoyang. Application Mode of Case-Based Teaching from the Perspective of Multi-modality in Ideological and Political Teaching Reform [J]. Journal of Changchun Normal University, 2021,40(03):176-181.
[2] Liao Li. On the Application of Case-Based Teaching in Undergraduate Teaching of International Law [J]. Legality Vision, 2015(23):288-290.
[3] Cheng Quan. Discussion on Curriculum Reform of International Law under "the Belt and the Road Initiative"—taking "The Law of International Organization" as an Example [J]. Legal System and Society, 2020(13):204-206.
[4] Yang Wei. On the Application of International Current Affairs and News in the Teaching of International Law [J]. Legality Vision (published in the mid-month), 2014(12):323.
[5] Zhong Yubo, Wu Zhe, Meng Jingying, An Taiji. Effective Application of Case-Based Teaching in College Ideological and Political Courses—taking "Carrying Forward the Chinese Spirit and Building a Spiritual Home Together" as a Teaching Example [J]. Modern Vocational Education, 2021(24):134-135.
[6] Tang Hua, Jiang Miao, Wang Hao. Reflection on Introducing Case-Based Teaching to College Ideological and Political Curriculum [J]. The Party Building and Ideological Education in Schools, 2018(21):63-64.
[7] Xin Jinqin. Viewshed Analysis of Case-Based Teaching in College Ideological and Political Curriculum [J]. Yangtze River Series, 2018(21):208-209.
[8] Zhu Yu. Analysis for Case-Based Teaching of International Law for Law Undergraduates in Local Colleges and Universities [J]. Education Modernization, 2017, 4(44):154-157.
[9] Li Chen, Qu Dawei, Meng Weijun. An Empirical Study on Application of Case-Based Teaching in Specialized Course "Ideological and Political Education" [J]. Journal of Ningbo Institute of Education, 2019(21):1-4.
[10] Min Hui. Education Function of Ideological and Political Education, as well as Philosophy and Social Science in Colleges and Universities. [J]. Ideological and Theoretical Education, 2017(7):21-25.
[11] Rao Geping. Ontology, Object and Scope: A Discussion on the Basic Issues of International Organizational Law [J]. International Law Research, 2016(1): 63.

[12] Liu Bin. A tentative discussion on the reform of undergraduate teaching of international law in China [J]. International Law Review of Wuhan University, 2015(1):388-389.

[13] He Zhipeng. The "Tao" and "Technology" of China's International Law Teaching Improvement [J]. Chinese University Teaching, 2017(4): 320.

Research on the Application of Big Data in Teaching Quality Monitoring Platform of Local Colleges and Universities

Jiaming ZHONG and Lijuan YE[1]
Xiangnan University, Chenzhou City, Hunan Province, 423000, China

Abstract. [Purpose] Through analyzing the characteristics of higher education, a teaching quality monitoring big data platform of local colleges and universities is constructed. [Methods] The data base of basic teaching state is applied to the teaching quality monitoring system, to improve the information gathering, processing, and feedback ability of quality monitoring, as well as to enhance the working efficiency and quality of monitoring. [Conclusion] The platform framework consists of business management information system, database, data analysis, data application and so on. [Suggestions] Based on database, the platform input the systematic data of all kinds of businesses in the data center into database, offering fundamental data support to systems like state database, academy evaluation, and application for the first-of-class majors. Then, these data can be obtained automatically, and processed to the fundamental basis required by all the systems, providing teaching quality monitoring and evaluation, and big data analysis for both universities and its affiliated institutes. On the other hand, the data generated by the system can be pushed to the data center of the university.

Keywords. big data; local colleges and universities; teaching quality monitoring

1. Introduction

The combination of big data and education has become the development trend of the times.[1] During the whole process of educational activity, educational big data collects the data set, which can create huge potential value and can be used for educational development based on educational requirements. Educational big data in colleges and universities can be divided into four types.[2] The first type is teaching management, which refers to the data generated during the process of teaching management, including student information, teachers' information, course information, and teaching plan. They are mainly structured data. The second type is teaching process, which is behavioral data during students' learning process, such as course learning, homework complement, after-class question answering, and examination. They are mainly online structured data. The third type are teaching resources, including course video, texts, test

---
[1] Corresponding Author, Lijuan YE, Xiangnan University, Chenzhou City, Hunan Province, 423000, China; Email: lijuanyecn@163.com

questions, and homework, which are mainly online and structured data. The fourth type is behavior, such as daily check in, communication, activity participation, and task completion.

Through the big data platform of teaching quality monitoring in colleges and universities, with the use of information methods and network technology, a regular monitoring mechanism for teaching quality in undergraduate schools can be constructed by combining the data reporting, data interpretation, and in-depth data mining of basic data from teaching. This can accelerate the information process of college management, and promote scientific management and decision-making.[3-4]

In October 2013, the Ministry of Education (MOE) of the People's Republic of China released the "Opinions on the Evaluation of Undergraduate Education in Ordinary Colleges and Universities",[5] which clearly pointed out that "based on self-assessment of colleges, taking academy evaluation, major certification and evaluation, international evaluation, and regular data monitoring of basic teaching state as main contents, a teaching evaluation system suitable for modern higher education system with Chinese characteristics will be constructed by combining multiple evaluation elements, such as government, schools, professional organizations, and society." The evaluation system is short for "five in one". It is a problem that every college urgently needs to work out about how to apply information tools, fully dig out the data value, improve work efficiency, and aid the college quality monitoring evaluation. Therefore, constructing a teaching quality monitoring platform for colleges and universities is a necessary measure to comprehensively push forward cultural construction of college quality, and to deepen the teaching reform of undergraduate education.

2. Existing Problems of Constructing Local College Big Data Platform

2.1 Lacking Database, and Low Data Availability

Some colleges haven't built up the data base aiming at the national higher education quality monitoring data, so the reported data are saved in forms or uploaded to national platforms.[6] Traditional data saving methods have greatly impeded the utilization of college data, so that the data value is extremely limited for colleges. For example, when making major certification, the basic information of professional teachers and students, their awards, and publications should be reported, so it is very difficult to inquire and reuse the data, thus reducing the work efficiency and accuracy. By making use of information platform, users can directly retrieve related data, and can manage the state data, basic information form of colleges, and the first-class data of the major. Therefore, there is no need to gather the data repeatedly.

2.2 Irregular Data Input

The national higher education quality data monitoring platform has opened to the colleges and universities since 2016. All the universities report their data based on the "reporting guidance", which would be updated and changed every year, or several times in a year. Therefore, it requires that the colleges has a deep understanding of the guidance, and keep up with the changes, to make sure that the data in the report accord with national standards. However, in reality, reporting data is only a periodical task. Sometimes, the data input may be irregular, because the responsible teacher may not

have an accurate understanding about the guidance, and they haven't kept up with the updates, or just because of their common understanding. For example, the coverage of students and the refined classification of tutors are among the problems.

2.3 No Closed-Loop Management for Quality Monitoring, and No Tracking for Reformation Effect

The purpose of teaching quality evaluation is not only to discover problems, but also to sustainably track and adjust the improvement or reformation effect of the problems. When tracking and following the problems, we can not only understand the improvement effect of teachers, but also adjust the direction and focus of teaching quality monitoring in time according to the problem feedback, so that the inspection for teaching quality will be more suitable for the teaching methods of the school. What's more, the reformation effects can be compared and analyzed, and can be regarded as the basis for assessing teachers' development and growth.

3   Conclusion

3.1 Big data Analysis Platform Framework of Teaching Quality Monitoring in Local Colleges and Universities

Construct the big data analysis platform of quality monitoring in universities, the framework of which is shown in Figure 1.
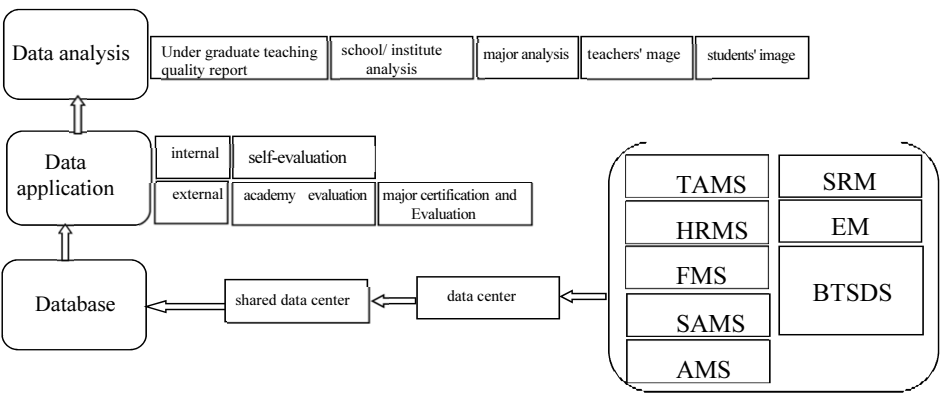
Figure 1. Bigdata Platform of Teaching Quality Monitoring

(1)   Data analysis

     Including: undergraduate teaching quality report, school/institute analysis, major analysis, teachers' image, students'image.

(2)   Data application

     Including: internal(self-evaluation); external(academy evaluation, major certification and evaluation).

(3) Database
  Including: shared data center, data center.

(4) Management information system
  Including: Teaching affairs management system(TAMS), Human resource management system(HRMS), financial management system(FMS), students' affairs management system(SAMS), asset management system(AMS), scientific research and management system(SRMS), experimental management system(EMS), basic teaching state database system(BTSDS).

4 Suggestions

4.1 Contents of Platform Construction

Based on database, the platform input the systematic data of all kinds of businesses in the data center into database, offering fundamental data support to systems like state database, academy evaluation, and application for the first-of-class majors.[7] Then, these data can be obtained automatically, and processed to the fundamental basis required by all the systems, providing teaching quality monitoring and evaluation, and big data analysis for both universities and its affiliated institutes. On the other hand, the data generated by the system can be pushed to the data center of the university. The main contents of project construction are as follows:

4.1.1 State Data

The data module of basic teaching state of colleges are the set of related basic functions conducted by surrounding the state data,[8] including state database, data report, data confirmation, index analysis, and data analysis report. The application of this module doesn't need the set of other functions, which completely match the quality monitoring data platform of higher education.

(1) Database
The data on the national platform from previous years can be input with one click, and the data from the first-of-class reporting platform, together with the basic statistics report of higher education can be input with one click. For diversified data collection, the data sheet collection can be customized, which can also be linked with the data from business systems, such as data center, teaching affairs system, personnel system, and student affairs system.

(2) Data Report
The data analysis report of verification evaluation, undergraduate teaching quality report, professional state analysis report, the monitoring report of normal major certification, and the data analysis report of major certification can be generated. Meanwhile, the data analysis report of the majors, such as clinics, engineering, and agriculture, to be put online can also be generated. The calculation methods of core indexes in the report coincide with those of national platform, and are updated synchronously.

(3) Data Analysis

According to the collected state data, the system can directly analyze related index, which completely includes the analytical indexes on the national platform. Meanwhile, more thorough analysis and comparison about the data will be conducted based on the "Briefing of National Monitoring Quality Check" published by the Ministry of Education, as well as the annual report of college teaching quality collected by utilizing big data analytic tools. For instance, the comparison of the core index tendency of college state data in recent three years, comparison between the core index with the regular module value at the same layer, with the same properties, and the same type, and the comparison of all the majors in terms of teachers, students, and courses.

4.1.2 Verification Evaluation

According to the division of "five-in-one" evaluation system, college and university verification belongs to the academy evaluation, which includes the budget for the verification and evaluation procedures, data analysis, online report presentation, connection of supportive materials, and online inquiry.

(1) Online Data Analysis and Report. On the platform, users can not only directly look through the analysis report of evaluation data generated by state data, but also the number of abnormal indexes about objective indexes in each chapter can be presented before it. Therefore, it is convenient for users to find out abnormal data.

(2) Inquiry of Supportive Materials. Targeting at evaluation system, users can connect it with supportive materials from supportive material base, and transform their format. Meanwhile, the supportive materials after connection allow online preview of evaluation experts, so that experts can access to the materials, to enhance the work efficiency of evaluation, and to reduce the work pressure of experts.

(3) Rehearsal of verification evaluation can be organized on the platform, and colleges can help set up index system, including initiators, department reviewers, and expert opinions. After all these procedures, the verification and evaluation report can be previewed online.

4.1.3 Internal Evaluation

Internal evaluation mainly serves all kinds of evaluation and certification tasks that are developed in the college by themselves, featuring the characteristics of flexibility, customization, and openness. The evaluation subjects include schools, institutes, majors, and courses. The specific functions are as follows:

(1) Management of Evaluation Standards

The management function of evaluation standards is to set up different evaluation systems in line with different evaluation subjects, including schools, institutes, majors, and courses. In each evaluation subject, different types of index systems can co-exist. For example, in major evaluation, the evaluation index system in the major of science and engineering can co-exist with the system in the major of literature and history, or even other types.

In each evaluation standard system, the parameters such as primary index, secondary index, tertiary index, index connotation, index attribute, standard value of quantitative index, index data source, and evaluation modes can be customized flexibly. The data source of quantitative index can be directly calculated from state data and customized data, while the evaluation mode consists of qualitative or quantitative mode, direct score, ranks and levels, and F/P.

(2) Management of Evaluation Tasks

The management function of evaluation task is to set up the implementation process of this evaluation task, such as the starting and ending time, self-evaluation stage, settings of evaluation experts, and the range selection of evaluation subjects.

(3) Implementation of Evaluation Tasks

According to the given evaluation mode, evaluation will be implemented. Objective indexes can be calculated automatically through data source, and corresponding values will be given, while subjective indexes will be converted by the scores or ranks given by experts.

(4) Presentation of Evaluation Results

Data will be analyzed through the scores of subjective and objective indexes. Then, the ranks of different subjects under the same index system will be compared, the scores of different subjects with the same index will be compared, and different scores from different experts for the same subject will be compared. Meanwhile, based on the template of analysis report, the platform can automatically present related analysis report.

4.1.4 Major Certification

Major certification can be used by schools to support the tertiary major certification work. Certification rehearsal can be carried out on the platform, to find out the weaknesses of the major, make adjustment with purposes, and enhance the passing rate of certification. This function consists of qualification analysis of certification indexes, online presentation of certification reports, self-evaluation report of certification, and major management of certification.

(1) Qualification Analysis of Certification Indexes

According to the state data, the qualification analysis for quantitative indexes with corresponding types can be calculated in terms of different majors, such as normal pre-elementary education, primary school, middle school, vocational education, and special education. Meanwhile, the unqualified elements of primary, secondary, and tertiary indexes will be pre-warned and alarmed.

(2) Online Presentation of Certification Report

Users can directly look through the state data, and then generate the analysis report on evaluation data. What's more, before each chapter of the report, the number of the objective index that is lower than the average value in the region will be indicated, so that it is convenient for users to look for the unqualified data.

(3) Self-Evaluation Report of Certification

Offer the presentation of self-evaluation report uploaded by the certificated majors.

(4) Management of Certificated Majors

Users can manage the majors that have passed the national major certification, to understand the certification period, the passing time, and other situations. Therefore, it is convenient to order the certificated majors to prepare for their annual report.

4.1.5 Panoramic Data Analysis for the Major

As the focusing unit of teaching quality monitoring and evaluation certification, major is the pivot for the operation of college teaching. The quality of major construction directly determines the quality of the students it develops, so it is extremely necessary to analyze the panoramic data of the major. The analysis includes the comparison between this major and the national average value, the comparison of the average value in the provinces, the comparison of international standards among the main type, and the analysis report of the panoramic data.

(1) Comparison of Average Value of Panoramic Data

It helps compare the index result of state data for this major with the average value of this major around the country, compares it with the provincial average value. Special marks will be given to the indexes lower or higher than the average value.

(2) Comparison of National Standards with Panoramic Data

Extract some data from professional talent development programs by making use of data analysis tools, compare them with the education quality standards of the 92 major types released by our country, and warn the situations of the program that do not comply with or satisfy national standards. Then, dig out the data, and understand the sources for the problems in details.

(3) Panoramic Data Analysis Report of the Major

This report is a summary of the overall situation of the major by combining the state data and some third-party data. Through the index system, weight, and calculation rules, the system can summarize the major in a fast, convenient and objective way. The report includes the ranks of the major, the comparison of the scores of the major, and the repeated contents of different major courses. It is a significant supportive material for schools to find out the real situation of the major, adjust the dynamics of the major, and adjust the threshold value of the major evaluation.

4.1.6 Teaching Evaluation

(1) Basic Data

Basic data includes the data of different departments in the school, basic information sheet of the major, information sheet of the class, information sheet of teachers, student information sheet, course information management, course opening, course arrangement, and course selection.

(2) Students' Evaluation of Teaching

- It supports customized index. Indexes can be selected according to different course types when assigning tasks.
- Managers can select the evaluation scope. The excluded scope refers to the targets of not taking part in the teaching evaluation, which does not included in the final data statistics.

- It supports online teaching evaluation, to fill in the suggestions and evaluation about teachers.
- Evaluation and the calculation of scores. By considering the college, the teacher, and the course, evaluation result and evaluation data will be calculated and analyzed.

(3) Lecture Evaluation

Support customized lecture evaluation index. With several systems, colleagues can set various types of questions.

There are two kinds of lectures that can be attended, given courses and optional. For the first type, managers should report the arrangement of the teachers expected to give lectures to related supervisors or leaders. On the other hand, optional courses can be selected according to the frequency of attending lectures, the lowest score of the lecture, random attendance, and personal selection. Then, the courses or lectures can be added to the list of lecture.

After arrangement of the lecture, task information would be sent to lecturers, in the form of systematic information, wechat, messages, or e-mail.

In my lecture, the arranged tasks and optional tasks can be viewed; support online evaluation from supervisors, leaders, and colleagues, as well as the evaluation from offline printed evaluation sheet.

For evaluation and calculation of scores, the evaluation results and data would be analyzed from the dimensions like college, teachers, and courses.

(4) Teachers Center

It supports feeding back the anonymous subjective evaluation messages from students' evaluation index to the evaluated teachers. After the teaching evaluation, the evaluated teachers can view the anonymous evaluation. The evaluation and opinion of the audience pushed by managers can be viewed, including the evaluation pushed by a single piece or together. Users can fill in some measures for improvement after viewing the evaluation, which would be fed back to managers.

(5) Questionnaire

Questionnaire management includes issuing questionnaire, setting questions, and view some details. The questionnaire includes anonymous questionnaire and real name questionnaire. Anonymous questionnaire can generate QR code and chained address. After scanning the QR code or logging in the chained address, users can fill in the questionnaire. Real name questionnaire can set up scope, and then issue questionnaires according to selected scope. When the questionnaire needs to add more questions, the indexes in shared index base and individual index base can be quoted, and the sequence of the index (title) can be changed through dragging. After issuing the questionnaire, the details of the issuing and the details of the question answering.

(6) Mobile Terminal

The mobile terminal mainly includes my lectures, evaluation management, my evaluation, and students' evaluation. Specific functions are as follows:

- Unfinished lecture arrangement and finished lecture arrangement can be viewed, and users can choose to listen to the lectures online;
- Revise and push the evaluation for lectures, or push the evaluation as a whole. Summarize course evaluation, report the opinions, and push to the teacher.

- Single evaluation push, as well as the lecture evaluation pushed to teachers as a whole can be viewed.
- Students are supported to fill in the evaluation for teachers on mobile terminal. The courses without evaluation, or the saved courses with evaluation can be viewed. However, the evaluation could be submitted after evaluating all the courses.

4.1.7 Images of Data

By summarizing and making the most of existing data, the images at the level of school, major, or teachers may be shaped. Meanwhile, the primary index presented by images can help dig out data, until data granules

It is the requirement of development in information era to apply the higher education national data platform (the database of basic teaching state) to the teaching quality monitoring system of local colleges and universities. Improving the information collection, processing, and feedback system of quality monitoring by means of information technology can enhance the work efficiency and quality of quality monitoring.

Acknowledgements

References

[1] Yang yang, Su Li, Shi Cheng. Advanced Strategy and Influence of Big Data on Education Management in Modern Colleges and Universities[J]. Jiangsu Higher Education, 2019,(3):58-61.
[2] Yu fang, Liu Yanshen. Big Data Portrait: An Effective Way to Realize Data-based Governance in Higher Education[J]. 2021,(3):50-57.
[3] WU Di, WANG Biao, LIU Zhiguo, ZHANG Qi, YU Jiang, XU Jiali. Construction of University Teaching Quality Monitoring System Based on Database Platform[J].SCI-TECH INNOVATION & PRODUCTIVITY 2017, (11):55-57.
[4] Liu Weidong, Huang Lei, Feng Ruowen. Reconstruction of Undergraduate Teaching Quality Management System Based on OBE Talent Training Model[J]. JOURNAL OF NATIONAL ACADEMY OF EDUCATION ADMINISTRATION, 2021,(10):19-30.
[5] the Ministry of Education (MOE) of the People's Republic of China. Opinions on the Evaluation of Undergraduate Education in Ordinary Colleges and Universities[EB/OL]. (http://www.moe.gov.cn/srcsite/A08/s7056/201802/t20180208_327120.html).
[6] Higher Education Evaluation Center (HEEC) of the Ministry of Education (MOE) of the People's Republic of China. (https://www.heec.edu.cn/pgzxyw/597083/index.html).
[7] Mao Jianqing, Liu meijia, Chenwenbo. The research on the scale and structure of under graduate teaching expenditures of first-class universities in China: the analysis based on under graduate teaching quality Reports of 39 world-class university in construction[J]. Journal of Higher Education Management, 2021, Vol 15(6): 33-47.
[8] Xu xiaodong. Research and application of national University teaching basic state database[J]. University Teaching in China, 2012,(4): 83-87.

Research on Teaching Reform of Financial Management Major in Applied Universities

Yuan XIAO and Jiaming ZHONG[1]
School of Economic and Management, Xiangnan University, Chenzhou, China

Abstract. With the popularization of big data, the requirement to accounting is getting higher and higher. How to improve professional ability and cultivate talents in line with the needs of the age is an important goal of current teaching reform. Based on the results of financial big data competition in Hunan Province, this paper analyzes the shortcomings in current teaching. The conclusion is students' application of professional knowledge needs to be strengthened. It is suggested that from the perspective of the needs of practical work, we should consolidate professional knowledge base, and teach students to flexibly use big data tools to assist financial work.

Key words. Financial big data; Applied university; Financial management major

1. Introduction

The competition of College Students' financial big data application ability in Hunan Province is a competition of comprehensive ability to use a number of big data technologies in a given application scenario, which focus on the ability of participating teams to develop and utilize financial big data, form data assets, solve social hot issues and meet the actual financial needs of enterprises. The theme of the competition is to take the investment and financing decision-making as the main line, and use big data technology to carry out data analysis and project decision-making on investment risk, financing risk and operation risk. The competition team consists of big data analyst, financing manager, investment manager and operation manager. Among them, big data analyst accounts for 30 points, and the other three positions total 70 points. The competition requires the teams to collect all kinds of data on the designated cloud platform, and these data sets are generated in the process of enterprise operation data, internal and external environment and business operation, financial data processing, etc. The competition is carried out by computer scoring and manual scoring. The questions are completed by experts designated by the expert committee, and the questions are kept secret and judges are avoided strictly to ensure the fairness and justice of the competition.[1][2]

Due to the need of epidemic prevention and control, the undergraduate group competition in 2020 is an online competition in which four teams are selected by the

---

colleges and universities to participate, Network game cooperation with exclusive network, using the skill competition website (http://race.chinazdap.com/). then the top 76 teams from all teams go to the Yuntang campus of Changsha University of technology for on-site competition. This paper is a data analysis based on the score of 76 teams in four decision-making links.

2.Methods

2.1 Big data analyst

The competition is conducted on the cloud platform of "exclusive network". The platform requires participants to be familiar with Python environment installation and configuration, big data acquisition, storage, cleaning and visualization. The main purpose of the competition is to investigate the ability of participants to capture financial big data by using tushare of Python and the ability of big data visualization programming. The big data score is shown in Figure 1 below.

The horizontal axis of the graph represents the number of teams scoring in their position
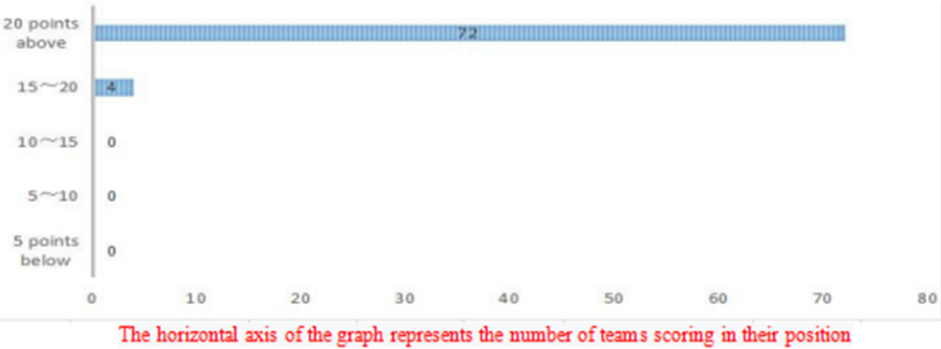
Figure 1 scores of big data analysts

It can be seen from the figure that the scores of big data analysts are mainly concentrated in more than 20 points, accounting for 94.74%, with the lowest score of 17.44 points, the highest score of 29.70 points, and the average score of 25.35 points, which is the highest among the four positions.

2.2 Financing Manager

The position of financing manager is mainly to make requirements for the participants from the aspects of absorbing direct investment, discovering stocks, retained earnings, bank loans, issuing bonds, financial leasing, issuing convertible bonds, issuing warrants, commercial credit, commercial factoring, pawn, pledge, etc. The score of financing position is shown in Figure 2 below.
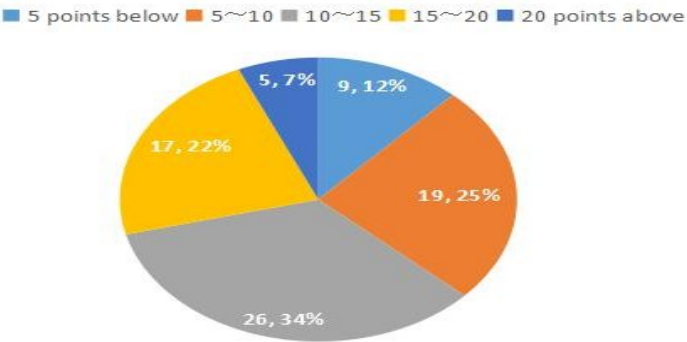
Figure 2 score of financing manager

Financing manager's post score is relatively low, comparing with data analyst's post score. There are 9 teams with scores below 5, 19 teams with scores of 5-10, 26 teams with scores of 10-15, 17 teams with scores of 15-20, and 5 teams with scores above 20. The post score presents normal distribution, with the lowest score of 3.03, the highest score of 21.2, and the average score of 11.73.

2.3 Investment manager

The assessment knowledge and skills of investment manager mainly focus on fixed assets investment, new subsidiaries and branches, portfolio investment, merger and contraction, cash, accounts receivable, inventory, intangible assets investment, etc. The score of investment positions is shown in Figure 3 below. The horizontal axis represents fractions.

The score of investment manager position is generally not ideal. There are 17 teams with less than 5 points, most of them (about 43 teams) are concentrated in 5-10 points, 14 teams with 10-15 points, 2 teams with 15-20 points, no team with more than 20 points, the lowest score is 2.07 points, the highest score is 16.12 points, and the average score is 8.04 points.
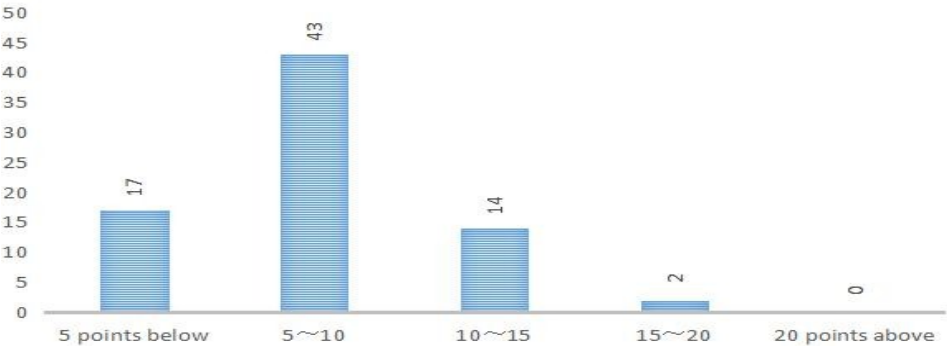
Figure 3 score of investment manager

2.4 Operations Manager

Operation management post is mainly to evaluate operation performance management, cost volume profit analysis, sensitivity analysis, marginal analysis, operation decision analysis and management accounting information report preparation. The score of operation position is shown in Figure 4 below. The horizontal axis represents fractions.
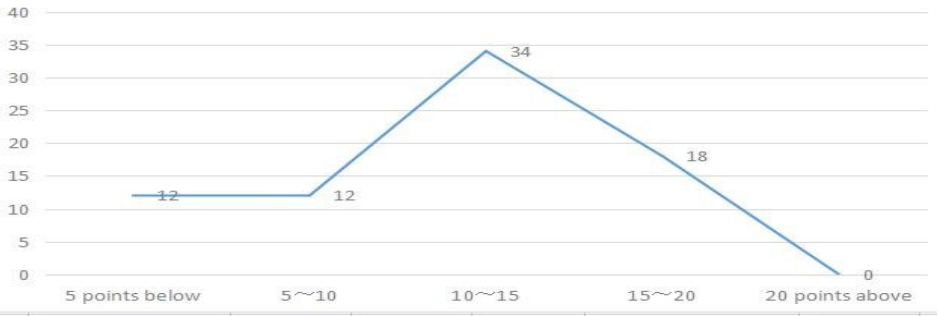
Figure 4 operation manager's score

The score of operation position is better than that of investment position. There are 12 teams with less than 5 points, 12 teams with 5-10 points, 34 teams with 10-15 points, 18 teams with 15-20 points, no team with more than 20 points, the lowest score is 0.95, the highest score is 19.5, and the average score is 11.28. The highest score is 81.66 and the lowest is 32.51.

3. Conclusion

Deficiency of teaching content of financial management major from the perspective of post score.

3.1 Unfamiliar with the content of cash flow

Among these four positions, the score of investment manager position is the lowest. Many students reflect that it is difficult to determine the cash flow of fixed assets renewal decision-making projects and new projects, especially when determining the related flow, the impact of related costs and non-related costs, opportunity costs, operating costs and investment plans on other projects of the company should also be reflected in the process of cash flow calculation. Many students have fuzzy decision-making methods for independent investment plans and mutually exclusive investment plans. In the syllabus of financial management major, the difficulty level of this part of the content is set at "high". In daily teaching, considering the majority of students' acceptance of the content of this difficulty level, this part of the content is directly discarded in limited class hours, and the teaching method is relatively simple, which is something you don't understand after self-study, you can discuss with the teacher after class. This directly led to many students in learning professional knowledge "automatically" to ignore this part.[3]

3.2 The knowledge of operation management can not be well applied to practice

Another position with lower score is operation manager, which is mainly taught in the course of management accounting. In this part, the CVP analysis is relatively simple, and there should be no problem in the calculation on the premise of correctly distinguishing between variable cost and fixed cost. But sensitivity analysis and marginal analysis are difficult for most students. Many students are easy to confuse the concepts of safety marginal rate, marginal contribution rate, operating rate of profit and loss critical point, sales profit margin before interest and tax, weighted average breakeven sales, sensitivity coefficient and the quantitative relationship between these concepts.[4]

4.Suggestions

4.1 Lay a solid foundation of professional knowledge

According to the feedback of financial management graduates in the past few years, when preparing for the CPA examination, many students found that in addition to the difficulty of the examination itself, there is also a problem that the basic financial knowledge is not solid enough. For example, the risk and return of single asset and portfolio in risk and return, capital asset pricing model, financial forecast and budget, bond value evaluation in value evaluation, option value evaluation and so on, although these basic knowledge do not belong to a specific course, they can be put into the syllabus, even if the students in the learning process can not be proficient, but at least this part of the content is not unfamiliar, in need of secondary acceptance of this part of knowledge will also understand faster.[5]

4.2 Improving the traditional teaching mode

The traditional teaching mode is that teachers teach knowledge in class and students accept it passively. Compared with other majors, financial management major is characterized by strong practicality. If the theoretical knowledge learned in textbooks is not guided to practice, many students are at a loss in their specific work. They seem to learn this part of knowledge, but they will not use it in practice. Although the flipped classroom and case teaching method have been brought about now, if the application-oriented university can establish the production, study and research base with local enterprises, make full use of the advantages of the combination of production, study and research, and strive to create a "three win" situation that meets the needs of enterprise talents, improves the "double teacher" quality of teachers, and enhances the practical ability of students.[6] [7]

Although the financial big data application ability competition is a simulation competition, its assessment content is more comprehensive and practical for financial personnel, so it is of practical meaningful to analyze the competition results as the analysis object for the daily teaching of financial management major. The financial professionals trained by application-oriented universities should be able to enter the professional role quickly and reduce the labor cost of enterprises. The ultimate goal of teaching is not to achieve excellent results in the competition, but to be competent for

financial work and constantly solve practical financial problems through four years of professional study of financial management knowledge.[8]

Acknowledgements

References

[1] Randy Garrison, Norman, D.Vaughan. Blended Learning in Higher Education: Framework, Principles and Guidelines[M]. San Francisco: John Wiley and Sons, 2007:71-83.
[2] Browne, Roger Hewitt, Martin Jenkins and Richard Walker,2008 survey of technology enhanced learning for higher education in UK[M].Universities and colleges Information systems Association.2008.
[3] Yang Shuyuan, Liu Fang, Fan Shu. Practical Exploration on the construction of local application-oriented undergraduate financial Management specialty -- A case study of Business School of Yunnan Normal University. Communication of Finance and Accounting, 2021,(24),154-158.
[4] Zhou Hui, Fu Guihai. Research on practical teaching of financial Management specialty in local application-oriented universities based on the concept of "entrepreneurship and innovation". Journal of Hunan University of Science and Engineering, 2020,41(05):109-111.
[5] Guirong Wang, HongXing Wang. Research on talent training mode of application-oriented undergraduate financial Management major from the perspective of industry and finance integration. Rural Economy and Science-Technology, 2020,31(13),334-335.
[6] Sun Rui, Liu ji. Embracing new Technology and leading the new development of Accounting Industry -- "Information Technology and the Future of Finance" Summit forum was held. Finance & Accounting, 2019,(13),84-85.
[7] HE Zubin, KONG Su. On the Applied Talent Cultivation of New-type Local Undergraduate Universities. Application-Oriented Higher Education Research, 2018, Vol3, (02): 1-4+10.
[8] Zhouxueling. Teaching Reform and Practice of Financial Management and Accounting specialty -- Comment on Teaching Reform of Financial Management specialty and Accounting Specialty. Journal of the Chinese Society of Education, 2016,(06): 140.

Immersive ERP Experiment Based on 3D-Reconstruction Model of Panoramic Images

Weibo HUANG[a, 1], Runlong WU[b] and Shuying KONG[c]

[a] Network and Information Center, Experimental Teaching Center, Guangdong University of Foreign Studies, Guangzhou, China.
[b] School of Finance, Guangdong University of Foreign Studies, Guangzhou, China.
[c] School of Economics and Trade, Guangdong University of Foreign Studies, Guangzhou, China.

Abstract. This study extends the application field of VR technology, and studies on the physical image problem of inventory management in ERP immersive experiment under VR technology, using the SSD block matching algorithm and the panoramic image in-depth information extraction algorithm to extract the two-dimensional in-depth information in the panoramic images. Then we reconstructed the object in 3D. The results show that the image reconstructed in 3D is clearer, more stereoscopic, and interactive, which solve the problems of low resolution, distortion, and low interaction in ERP virtual teaching environment, while using multimedia and camera roaming to enhance students' immersive experience, achieve high-precision, real scene, better virtual teaching environment interaction. It can be seen that the immersive ERP experiment based on VR technology is conducive to improving students 'professional ability and docking ability, as well as improving students' overall cognitive ability and operation ability of the ERP system.

Keywords. Panoramic image, 3D-reconstruction, SSD block matching Algorithm, VR, ERP

1. Introduction

In May 2021, China issued the Notice on the Pilot Work of Technology and Standard Innovation Demonstration Projects in the Publishing Industry. It focuses on the innovative research in the publishing field of new technologies such as big data, artificial intelligence, block-chain, cloud computing, the Internet of Things, virtual reality and augmented reality [1]. Augmented reality (AR), virtual reality (VR) and other technologies are generally called extended reality (XR), which refers to a technology that combines real and virtual reality through computers to create a virtual environment for human-computer interaction. In recent years, with the iterative update of VR technology products, VR technology has gradually played an important role in entertainment, production and other fields. VR technology has gradually entered the education and vocational training of primary and secondary schools, universities and enterprises. Studies by Zahira Merchant, Tassos A Mikropoulos, and others reviewed the VR design

---

in higher education and showed that people have an interest in using immersive VR techniques in many different fields [2]. A review of immersive VR application systems in higher education identifies engineering, computer science, and astronomy as the most popular applications. Other categories such as biology, geography, art, and chemistry are also applied areas of higher education. VR application teaching can enable students, teachers and users to devote themselves to a realistic environment of virtual learning through creation of situation. Meanwhile, the low-latency and high-broadband features of 5G technology provide the practicability for the interactive scenes applied to VR devices [3].

2. Current status of ERP immersive experiments

At present, the "China 5G + VR" webcast held by Huazhong University of Science and Technology, through the connection of "free of dead corner" teaching scene, teachers, system of knowledge, technical links and other aspects, makes the student learn mode changes. Guangxi University of Finance and Economics has built a holographic XR virtual training base, combining theory and practice, so students can fully master engineering professional knowledge. Beijing Normal University applies AR technology based on "VR / AR + education" laboratory research, hence students can easily conduct experiments which requirements are relatively high in mathematics, physics, chemistry, science and other subjects. VR technology has certain applications in many aspects of the education field. [4]

VR technology has become an auxiliary tool for education, which can simulate the real situation of the content of subject learning. By engaging students in the real situation for operation, it can reduce the experience cost and study cost of the subjects and guide students to carry out deep learning. [5]

Enterprise Resource Planning (ERP) was proposed by Gartner Group Company in 1990 and refers to the management platform based on information technology and providing enterprise decision-making levels and employees with systematic management ideas. However, the application of VR technology in ERP experiments is not common, and the ERP teaching in higher education generally uses the traditional teaching methods. That is, through the ERP sand table simulation for a simulation enterprise, the key links of the enterprise operation system and other operation mode are designed as the main content, showing the operation and management process of the enterprise in an all-round way. This experiential teaching method integrates teaching theory and practice, role playing and post experience, also provides better help in expanding students system of knowledge, establishing win-win concept and overall concept, and training students' enterprise business ideas.

Although higher education has already applied an experiential teaching method, students still have more needs in ERP experiments. The application of VR technology in the ERP experiment is a revolutionary teaching method. Our study is to apply the VR technology of panoramic image, 3D-reconstruction and other algorithm technologies, adding an immersive experience in the ERP teaching, to create a virtual and interactive ERP learning environment [6]. In the virtual environment, students can truly experience the content and process of professional work [7]. No longer limited to slice, single knowledge, students can access to the diversified content. Contrast with the universal traditional teaching mode, it can improve students' learning autonomy and solve the problem that it is difficult for students to experience the real environment and process of

working [8]. With reasonable architecture design and equipment support, "VR + ERP" is feasible.

3. 3D-reconstruction model based on panoramic images

3.1. VR technology

Virtual Reality (VR) is a technology to realize the combination of virtual and reality, and to build a virtual environment with a computer simulation system. It involves computer graphics, stereoscopic display technology, tracking technology of user interaction site and other subject fields. It was first proposed in Ivan Sutherland paper called "The ultimate display" published in 1965 in US. Then, a helmet display device and a head and hand tracker were successfully studied. Immersion, interactivity and conception are the three basic characteristics of VR technology [9]. At the same time, VR system has four different categories, they are mainly divided into immersive categories, non-immersive categories, distributed categories and augmented reality. This study focuses on the application of immersive VR systems in ERP experiments.

3.2. 3D-reconstruction model of panoramic images

The application of VR technology can improve the operability of students in ERP simulation experiments, and 3D-reconstruction can provide more considerable help for the implementation of ERP immersive experiments under VR technology. The 3D-reconstruction of VR panoramic image takes the panoramic image technology as the entry point, which has the advantages of relatively simple recording process, low support cost of related equipment, and can be applied to static and dynamic three-dimension scene capture, convenient to use and so on. We obtain the in-depth information on the distance between the pixel point and the camera by converting two-dimensional plane images into pixel coordinates in three-dimensional space and calculating the disparity. The panoramic image of the VR room can be constructed in three-dimension, so as to obtain a higher resolution and more realistic virtual teaching interaction environment.

The neighborhood restriction and relaxation methods to deeply extract the panoramic images, and fitted the expected value in a composition to determine the best disparity value, hence realized the 3D-reconstruction of the specific panoramic images

The basic steps of the algorithm are as follows.

For panoramic images, microlens arrays are usually used to display three-dimensional scenes. The in-depth information of the three-dimensional object is also recorded. Here we note D as the required in-depth information, d as the disparity of the selected views of two, Ψ as the aperture of the microlens array subunit, and F as the focal length of the microlens array subunit, Δs as the "baseline", representing the sampling distance of the two selected views ($\Delta s = ds_1 - ds_2$).

$$D = \frac{(d \pm 1) \cdot \Psi \cdot F}{\Delta s} - d_r \quad (1)$$

Where, F, d_r, Ψ are the parameter, in most cases, $d_r d_r \ll D$, so that the range of error and the range variation of d are not considered here. Simplify the formula to:

$$D = \frac{d \cdot \Psi \cdot F}{\Delta s} \quad (2)$$

Formula (2) indicates that the in-depth information of a panoramic image can be obtained through the disparity information and the parameters given a microlens array. In order to further obtain the in-depth information of panoramic images, the common matching algorithm is generally used to calculate. Here, a block matching algorithm based on the SSD calculation criteria is used to deeply extract the VR panoramic images.

Sum of Squared Differences is the SSD algorithm for short. That is, compute L2 distance between the sub-graph and template. Its formula is:

$$D(i, \ j) = \sum_{s=1}^{M} \sum_{t=1}^{N} [S(i+s-1, \ j+t-1) - T(s, \ t)]^2 \qquad (3)$$

This algorithm can perform image template matching by code running.

Block matching algorithm is a general term for computer algorithms used to find the same or similar image blocks as a given image block in a special image. It is based on the multi-window matching algorithm of Neighborhood Constraint and Relaxation. This algorithm can default that the in-depth space is continuous and segmented. The basic steps of the algorithm are as follows.

After shooting the same panoramic image at different angles, take the two views as P_1 and P_2 respectively, note that there are pixels $(x, \ y)$ in P_1 that matches P_2, and get the region of P_2 from $(x, \ y)$ that best matches P_1, noting as $(x+d, \ y)$, $d \in [-R, \ R]$.

The expected disparity value of block matching algorithm as obtained when taking the minimum value, that is:

$$d^* = \arg\left\{\min_{d \in R}\left\{\sum_{x, \ y \in \omega}[P_1(x, \ y) - P_2(x+d, \ y)]^2\right\}\right\} \qquad (4)$$

In the formula (4), $(x, \ y)$ is the pixel recording point coordinates. $P_1(x, \ y)$ is the intensity of the pixel recording point $(x, \ y)$, ω is the matching window to be specified, and R is the image pixel matching interval.

when we use multi-window matching algorithm of neighborhood restriction and relaxation, there is a sub-window $B_{i, j}$ of pixels $(i, \ j)$ and a neighborhood sub-window $B_{k, l}$ of pixels $(i, \ j)$. When conducting the analysis of the sub-window disparity d, we can consider its neighborhood sub-window together to obtain more effective results.

At this time, after considering the neighborhood relaxation, improving the neighborhood block and matching block determination criteria [6], it can be concluded that:

$$\text{score}(B_{i,j}, d) = \text{SSD}(B_{i,j}, d) + \sum_{B_{k,l} \in N(B_{i,j})} \omega(B_{k,l}, B_{i,j}) \text{SSD}(B_{i,j}, d) \qquad (5)$$

Here, $B_{i, j}$ is a sub-window of pixels $(i, \ j)$, and $B_{k, l}$ is $B_{i, j}$ a neighborhood sub-window. $\omega(B_{k,l}, B_{i,j})$ is the weight factor of the corresponding different neighborhood blocks, and $N(B_{i,j})$ is the neighborhood set of the matching blocks.

There is disparity between different neighborhood blocks, so different disparities will have different local presentation. Because the neighborhood blocks are different from the matching blocks. A variable is added to calculating SSD:

$$\text{SSD}(d) = \sum_{x, \ y \in \omega}[P_1(x, \ y) - P_2(x+d, \ y)]^2 \qquad (6)$$

Thus, when calculation, the neighborhood constraint is determined by the window SSD and the variable when the neighborhood is relaxed. Based on the subject, the minimum function score is the expected disparity value. However, there will be a residual

value after calculating with the SSD standard, so we define a threshold value R_{bp} that is θ times of the minimum residual value, there are:

$$R_{bp} = \theta \cdot min\_residue \qquad (7)$$

In the process of evaluating, we end up taking all values that are less than the threshold.

When values such as d_1, d_2, d_3 and so on are obtained by the score function are all less than the value R_{bp}, in order to find the most accurate expected value, we use that quadratic formula of a parabola that passes through the values d_1, d_2, d_3 and so on. At this time, the expected most accurate disparity value of the parabola is taken at the lowest point of the parabola, according to the definition of a parabola.

Panoramic image records the three-dimension spatial information in the form of two dimensions. That is, we can use above algorithm to extract the in-depth information in the two-dimensional view, applying the in-depth information to the 3D-reconstruction, so as to improve the resolution and reconstruction accuracy of the panoramic image. It can effectively solve the distortion problem of the traditional 3D-reconstruction.

3.3. Camera roaming and multimedia access

Enhance immersive experiment experience refers to the scene can get visual effect, into the camera roaming can let the users in the process of interaction with virtual environment more deeply feel the object and environment distance and line of sight change. With the movement of the object drove by the movement of the eyes, the specific content of the environment gets into the brain, as the eyes of the world in reality. Internet platforms can be used to find roaming interactions mode with specific VR devices. The ERP immersive environment mentioned in this article uses a hand sensing instrument to move up, down, right and around the line of sight through the rotation of the helmet.

Multimedia substitution refers to the import of the corresponding data markers in the ERP sand table simulation, which constructs the required animation (such as inventory object animation) through 3DSMax and other software, load the corresponding database of the VR device in the form of FBX, and then set the next step when using the VR device.

3.4. Solve the problem of scene and image of inventory management in immersive ERP experiment

After taking panoramic images of three-dimension objects in ERP experiments, such as warehousing-specific inventory items, the disparity values between different views are calculated according to the block matching algorithm. After extracting the in-depth information based on the given microlens array parameter, 3D-reconstruction can effectively improve the accuracy of inventory physical models in immersive ERP experiments. If the finished product mentioned in the purchase plan is physically photographed, we use the SSD block matching algorithm to the different two-dimension plane views obtained. Then we use the score function to find the most accurate disparity value d for different views, and use formula D of the in-depth information extraction to obtain the in-depth information for 3D-reconstruction.

The reconstructed panoramic images are applied to the VR image library, when students make inventory in and out in the ERP experiment through VR equipment, the modeling accuracy of the simulated items would be quite high. Its high resolution and

high precision stereoscopic-state when students touch the inventory items will give students a better simulation experience. That is, not only does the virtual scene in the ERP experiment become more realistic, interaction will also be higher when counting items. Thus the problem of inventory management image when students use technology to experience ERP experiment in an immersive way will be better improved, and further strengthen the students' practical operation ability in this aspect of the ERP experiment. The solution process is shown as Figure 1.
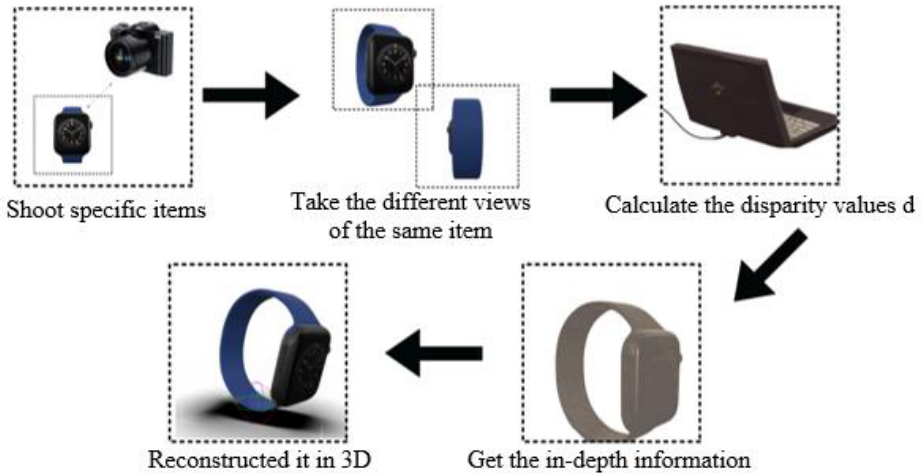
Figure 1.　Solution process

(1) The first step is to shoot specific items.

(2) The second step is to take the different views of the same item.

(3) Thirdly, the SSD block matching algorithm is used to calculate the disparity values d for two view-specific windows.

(4) At a given microlens array parameter, the disparity value d is replaced into the panoramic image in-depth information extraction formula D to obtain the in-depth information of the two-dimensional panoramic image.

(5) The in-depth information of the obtained panoramic image is reconstructed in 3 D and applied into the VR image library.

Through the above steps, it can improve the fidelity and interactivity of the immersive ERP warehousing management experiments under the VR technology and realize the high accuracy of item model.

4. Experimental results

This study used the SSD block matching algorithm and panoramic image in-depth information extraction algorithm to get the two-dimension in-depth information of panoramic image, and reconstructed it in three-dimension. We took photos for items of the assumed inventory management included in the ERP experiment, after taking different views by using the algorithm evaluation, we reconstructed two-dimension panoramic image of items in three-dimension, importing data into the VR database for inventory management process in immersive ERP experiment.

Here, we compared the three properties for stereoscopic, resolution and precision. First, the stereoscopic, resolution and precision of input and output images were relatively low before 3D-reconstruction.

Then the experimental results show that, compared with the images of virtual objects in the ordinary VR database, the virtual objects reconstructed by the SSD block matching algorithm are more accurate in VR. The model has strong stereoscopic sense and their resolution and interaction are also better improved. It solves the problems of easy penetration, distortion and low resolution of virtual objects in the process of traditional VR technology interaction.

5. Conclusion

Based on panoramic image 3D-reconstruction algorithm of VR technology, ERP experiment system can intuitively show the actual operation of the ERP inventory management sand table simulation. By using 3D-reconstruction algorithm, the deeper information in two-dimension panoramic image can be accurately expressed, having higher accuracy, a more real scene, and better interaction effect virtual teaching environment. At the same time, it can enhance the simulation accuracy of the inventory items, so that the students can have better interaction in the simulated inventory business practice, and improve the students' training level and ability of practical operation. For the current traditional ERP teaching mode, under the aid of VR technology, emerging teaching mode has certain advantages. In view of the current trend, immersive ERP experiment has its validity of attempt to develop. Through VR technology, it enables students to be professional, improve students' docking ability, and improve the integrity cognition of students to ERP system and practical operation ability.

Finally, based on the ERP experimental model design of panoramic image 3D-reconstruction algorithm under VR technology, there are still many problems to be solved, this paper only for VR technology of ERP immersive experiment inventory management warehousing physical image problem is studied, how VR technology in ERP system in other fields and other processes also need deeper studies and discussions, which provides the direction for the future research.

References

[1] Soto J , Ocampo D , Colon L , et al. Perceptions of ImmerseMe Virtual Reality Platform to Improve English Communicative Skills in Higher Education. International Association of Online Engineering, 2020(07).

[2] Zhang J , Zhu T , Zhang A , et al. Multiscale-VR: Multiscale Gigapixel 3D Panoramic Videography for Virtual Reality[C]// 2020 IEEE International Conference on Computational Photography (ICCP). IEEE, 2020.

[3] Chen Y , Zhang B , Zhou J , et al. Real-time 3D unstructured environment reconstruction utilizing VR and Kinect-based immersive teleoperation for agricultural field robots. Computers and Electronics in Agriculture, 2020, 175(2020):105579.

[4] Lobachev O , Berthold M , Pfeffer H , et al. Inspection of Histological 3D Reconstructions in Virtual Reality. 2021.

[5] Ladwig P , Pech A , Drner R , et al. Unmasking Communication Partners: A Low-Cost AI Solution for Digitally Removing Head-Mounted Displays in VR-Based Telepresence. 2020 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR). IEEE, 2020.

[6] Han L , Zheng T , Zhu Y , et al. Live Semantic 3D Perception for Immersive Augmented Reality. IEEE Transactions on Visualization and Computer Graphics, 2020, 26(5):2012-2022.

[7] Zikas P , Papagiannakis G , Lydatakis N , et al. Immersive visual scripting based on VR software design patterns for experiential training[J]. The Visual Computer, 2020(3).

[8] Caserman P , Garcia-Agundez A , Gbel S . A Survey of Full-Body Motion Reconstruction in Immersive Virtual Reality Applications. IEEE Transactions on Visualization and Computer Graphics, 2020, 26(10):3089-3108.

[9] Piroozfar P , Essa A , Boseley S , et al. Augmented Reality (AR) and Virtual Reality (VR) in construction industry: An experiential development workflow. The Tenth International Conference on Construction in the 21st Century (CITC-10). 2018.

Mining Maximal Fuzzy Colocation Patterns

Meijiao WANG, Yu CHEN, Libo HE and Yunyun WU[1]
Yunnan Police College, Kunming, China

Abstract. Spatial colocation pattern mining is to discover the subsets of spatial objects frequently appearing together in adjacent geographic locations. In the existing research, several algorithms were proposed for excavating maximal prevalent colocation patterns. Furthermore, fuzzy neighborhood relationship(FNR) was employed to evaluate the proximity between spatial instances for improving the accuracy of the mining results. However, the approach for discovering the maximal prevalent colocation patterns based on FNR is not studied yet. This paper defines the maximal fuzzy prevalent colocation pattern (MFPCP). We propose a maximal fuzzy prevalent colocation pattern mining algorithm to generate the MFPCPs instead of all of the prevalent colocation patterns. We conduct experiments on the real datasets to evaluate the performance of the proposed algorithm.

Keywords. Spatial colocation pattern mining, maximal fuzzy prevalent colocation pattern, fuzzy neighborhood relationship, fuzzy instance tree

1. Introduction

Spatial colocation pattern mining which is an important branch of spatial data mining has attracted more and more attention in recent years. A spatial colocation pattern is a subset of spatial objects of which the prevalence index is no less than the prevalence threshold. The instances of its objects are frequently located together in adjacent space. Spatial colocation pattern mining is mainly applied in the following domains: Biology, Earth science, transportation, public health, etc. [1].

According to the downward closure property of prevalent colocation patterns, a prevalent colocation pattern is maximal when any of its subsets is prevalent while all of its supersets are not prevalent[2-4]. This means that all of the prevalent colocation patterns can be deduced from the maximal prevalent colocation patterns. Since the number of maximal prevalent colocations is much smaller than that of all prevalent colocations, maximal co-locations is more convenient for people to use.

Tobler's First Law demonstrates that the contributions of instances to their pattern's effect decrease along with the distance diminishes. To take into account the proximity level between instances in mining maximal prevalent colocations, Yao etc. proposed the SGCT-K algorithm[5]. SGCT-K employed a kernel density estimation (KDE) model for evaluating the proximity level between instances, and defined a KDE-based prevalence index (PI-K) as the prevalence measure of a colocation. Our previous research [6] defined the fuzzy neighborhood relationship(FNR) to evaluate the proximity level between instances, and proposed the CPFNR algorithm for mining

---

[1] Corresponding Author: Yunyun WU, Yunnan police college, 249 Jiaochang North Road, Wuhua District, Kunming City, China; E-mail:156799251@qq.com.

colocation patterns based on FNR for improving the accuracy of mining results. The PI-K in SGCT-K is so small that it is hard to set a prevalence index threshold to filter the prevalent colocations.

It can be seen from the above that it's very meaningful to mine maximal fuzzy prevalent colocation based on FNR. The major contributions are as follows:

(1) Based on the FNR and the downward closure of prevalent colocation patterns, we define the Maximal Fuzzy Prevalent colocation Pattern (MFPCP).

(2) Put forward a maximal Fuzzy Prevalent colocation Mining(MFPCM) algorithm for obtaining the MFPCPs.

(3) The efficiency of the MFPCM algorithm are evaluated by experiments.

The related works is stated in Section 2. Section 3 describes the relative definitions. Section 4 presents the algorithm. Section 5 performs the experiments to evaluate the presented algorithm. Finally, a summary is given in Section 6.

2. Related Work

Shekhar et al. first defined the concept of spatial colocation pattern[7]. They employed the participation index to measure the prevalent level of a colocation. Huang et al. present the join-based strategy for mining colocation patterns[1]. It was an Apriori-like algorithm which generated the prevalent colocations from short to long size. Because the table instance connection process consumed a lot of time, the papers [8,9] proposed the join-less algorithm and the partial join algorithm respectively. For efficiently pruning the candidates and reducing the memory usage for storing table instances, the CPI-tree algorithm[10] and the iCPI-tree algorithm[11] constructed the prefix-tree structure for reserving the table instances. Wang et al. studied the SPI-closed colocation discovery approach[12,13]. For massive spatial data, the work in [14,15] studied parallel colocation mining algorithms on map-reduce platform. The fuzzy set theory was adopted in the colocation discovery[6,16-19]. Especially, FNR was used to improve the accuracy of the prevalence index calculations in [6]. To reduce the number of prevalent colocations, mining maximal colocation patterns was disposed in [2-4]. But as far as we know, no work had been conducted on mining the maximal fuzzy prevalent colocation patterns based on the FNR, which will be addressed in this paper.

3. Related Definitions

Table 1 lists the abbreviations of the important concepts in this paper.

Table 1. the abbreviations of the important concepts.

Notations	Meaning	Notations	Meaning
O	spatial objects set	k	size of a colocation pattern
S	spatial instance set	FNR	fuzzy neighborhood relationship
s_u^i	an instance of o_u	FNR_a	α-cut set of FNR
c	a co-location pattern	FPR	fuzzy participation ratio
μ	membership function of FNR	FPI	fuzzy participation index
α	membership threshold of FNR	MFPCP	maximal fuzzy prevalent colocation pattern
d	the Euclidean distance	*min_fprev*	minimum fuzzy participation index threshold

Spatial objects (spatial features or attributes) represent different kinds of things in space. Let $O = \{o_1, o_2, ..., o_N\}$ be the spatial object set of N objects. Spatial instances are the appearance of spatial objects in different geographical locations. The spatial instance data sets is denoted as S, $S = \{s_1, s_2, ..., s_n\}$ is the set of n instances. For the objects o_u ($1 \leq u \leq N$), an instance of o_u is denoted as $s_u^i (1 \leq i \leq |S_u|)$.

3.1 Colocation Pattern mining Based on FNR

Definition 1(fuzzy neighborhood relationship(FNR)) . Let $D(D \rightarrow [0,\infty))$ be the Euclidean distance set between instances in S. The FNR of S is a fuzzy subset on D, which is formalized by the following mapping:

$$\text{FNR:} D \rightarrow [0,1], d \rightarrow \mu(d)$$

where, μ is the FNR's membership function, $d(d \in D)$ denotes the Euclidean distance between instances in S, $\mu(d)$ represents the membership value of d and it is exactly the probability of d pertinent to FNR.

Let $dist(s_i, s_j)$ be the Euclidean distance between two instances s_i and s_j. Then FNR can be expressed as:

$$\text{FNR} = \{<(s_i, s_j), \mu(dist(s_i, s_j))> | s_i, s_j \in S\} \tag{1}$$

The **α-cut set** of FNR is denoted as FNR_a which is defined as :

$$FNR_\alpha = \{< (s_u, s_v), \mu(dist(s_u, s_v))> | \mu(dist(s_u, s_v)) \geq \alpha, (s_u, s_v \in S)\} \tag{2}$$

where $\alpha \in [0,1]$ is a pre-defined **membership threshold**, and s_u and s_v are regarded as a **FNR_a neighbor pair** that will be connected by a solid line in the diagram of the datasets.

Example 1. Let $\alpha = 0.2$. An example data sets is illustrated in Figure 1. It is convenient to obtain that $\mu(dist(\text{B.1,C.2})=0.75$ and $<(\text{B.1,C.2}),0.75> \in FNR_\alpha$.

Let c be a **colocation pattern**, $c \in O$. Let I be a subset of S, $I \subseteq S$. I is called *a* **fuzzy row instance** of c, if I meets all of the following requirements:

(1) The size of I is equal to that of c.

(2) The object type of each instance in I is the same as that of c in the corresponding order.

(3) The instances in I form a clique under the FNR_a.

A fuzzy row instance of c is denoted as FR(c). All row instances of c compose the table instances of c denoted as FT(c).

Example 2. In Figure 1, let $c = \{A,B,C,D\}$, FT(c) = {{A.3,B.1,C2,D.3}, {A.2, B.2, C.1, D.1}, {A.4, B.4,C.3,D.2}}.
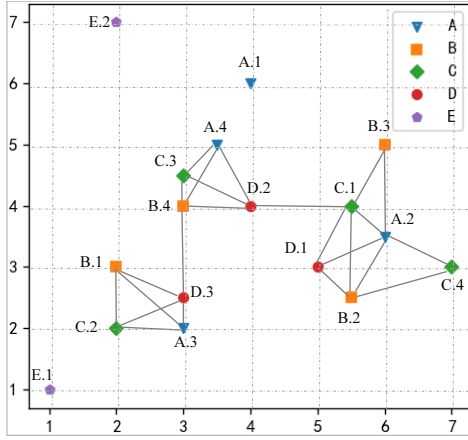
$$\mu(d) = \begin{cases} 1 & d < 0.5 \\ -\dfrac{1}{2}(d-0.5)+1 & 0.5 \le d \le 2.5 \\ 0 & d > 2.5 \end{cases}$$

(b) membership function

$< (B.1,C.2), 0.75 >$
$< (B.1,C.3), 0.35 >$
$< (B.2,C.1), 0.5 >$
$< (B.2,C.4), 0.46 >$
$< (B.3,C.1), 0.69 >$
$< (B.4,C.3), 1 >$

(a) distribution of data

(c) $FNR_a(B,C)$

Figure 1. An example data sets.

Definition 2(the contribution of an instance). Given a fuzzy row instance FR(c), the instance $s_i \in FR(c)$, the contribution of s_i is defined as the minimum membership value of all of the membership values between s_i and its fuzzy neighbors in FR(c), i.e.,

$$contri(FR(c), s_i) = min_{j=1}^{m}(\mu(dist(s_i, s_j))), i \neq j \tag{3}$$

Definition 2(fuzzy participation ratio(FPR), fuzzy participation index(FPI)). The FPR of $o_u(o_u \in c)$ is defined as the ratio of the sum of the contributions of non-repeating instances of o_u in FT(c) to the total number of o_u's instances, i.e.,

$$FPR(c, o_u) = \frac{\displaystyle\sum_{s_u^i \in FR(c), FR(c) \in FT(c)} Max(Contri(FR(c), s_u^i))}{|o_u|} \tag{4}$$

where, $Max(Contri(FR(c), s_u^i))$ refers to that the maximal contribution is added to the sum when s_u^i is repeated in $FT(c)$.

The minimal FPR of the FPRs of all objects in c is regarded as the FPI of c :

$$FPI(c) = min_{u=1}^{k}\{FPR(c, o_u)\} \tag{5}$$

Given a pre-defined FPI threshold *min_fprev*, if $FPI(c) \ge min\_fprev$ then c is fuzzy prevalent .

Example 3. In Figure 1, $FPR(\{B,C\},B)$ = (0.75+0.5+0.69+1)/4 = 0.735, $FPR(\{B,C\},C)$ = (0.75+1+0.69+0.46)/4 = 0.725, then $FPI(\{B,C\})$ = min(0.735,0.725) = 0.725. If *min_fprev* = 0.3, then {B,C} is prevalent.

3.2 Properties and Related Definitions

Lemma 1 (Monotonicity of FPR and FPI). Let c' and c be two colocation patterns, $c' \subseteq c$. For each object $o \in c'$, $FPR(c', o) \ge FPR(c, o)$. In addition, $FPI(c') \ge FPI(c)$.

Definition 3 (Maximal Fuzzy Prevalent Colocation Pattern(MFPCP)). For a colocation pattern *c*, if any subset of *c* is fuzzy prevalent while any superset of *c* is not fuzzy prevalent, *c* is called a Maximal Fuzzy Prevalent Colocation Pattern(MFPCP).

　　Example 4. In Figure 1, *FPI*({A,B,C,D}) = 0.434, {A, B, C, D} is a MFPCP. Because its subsets {A, B, C}, {A, B, D},{A, C, D} and {B, C, D} are all fuzzy prevalent, while its superset {A, B, C, D, E} is not fuzzy prevalent.

4. Algorithm

In this section, the algorithm for Maximal Fuzzy Colocation Pattern Mining(MFCPM) is designed by improving the SGCT algorithm given in [4]. It is described as follows:

Algorithm 1. the MFCPM algorithm	
Input: $O, S, \mu, \alpha, min\_fprev$ **Variables**: k: size of a colocation pattern CP: candidate maximal colocation set CP_k: size-k candidate set TI_k: table instance of a size-k candidate MP_k: size-k maximal fuzzy prevalent set MP: maximal fuzzy prevalent colocation set $ITree$: fuzzy instance tree of a candidate **Output:** MP with $fpi \geq min\_fprev$	**Steps:** (1) FNR = get_FNR (S, μ); (2) CP_2 = gen_candidate_colocations(O); (3) TI_2 = get_table_instances(CP_2, FNR_a); (4) P_2 = select_prevalent_colocations(CP_2, TI_2, min_fprev); (5) CP = gen_maximal_candidates(P_2) *(6)* k = longest_size (CP) (7) while(not empty CP) do (8) 　　CP_k = gen_size-k_candidate_colocations(CP,k); (9) 　　for each c in CP_k (10) 　　　$ITree$ = constuct_instance_tree(c) (11) 　　　TI_k = get_table_instances(c, $ITree$) (12) 　　　fpi = calculate_fpi(c, min_fprev, TI_k) (13) 　　　　if $fpi >= min\_fprev$ (14) 　　　　　$MP_k = MP_k \cup c$ (15) 　　　　else (16) 　　　　　$CP = CP \cup subset(c)$ (17) 　　end for (18) 　　$MP = MP \cup P_k$ (19) 　　$k = k - 1$; (20) end do

　　The main steps of the MFCPM algorithm are as follows:

　　Step 1 (FNR$_a$-table construction): Based on the membership function μ and membership threshold α of FNR, the grid division technique is adopted to calculate the FNR$_a$ of the spatial data set. We build the FNR$_a$-table which is a two-dimensional hash table for storing the FNR$_a$ of the spatial data set. Two object types are used for indexing each cell in the FNR$_a$-table. They form a size-2 candidate maximal colocation pattern.

　　Example 4. Figure 2 illustrates the FNR$_a$-table of the data sets demonstrated in Figure 1. The cell FNR$_a$(B,C) in the FNR$_a$-table represents the FNR$_a$ of the candidate size-2 colocation {B,C}.

Figure 2. the FNR$_a$-table of the example data set.

Step 2 (size-2 fuzzy prevalent colocations generation): Generate size-2 candidate colocations from spatial objects and then obtain the table instance for each candidate from FNR$_a$-table. Filter the prevalent colocations whose FPI is not less than *min_fprev*;

Step 3 (candidate MFPCPs generation): The two objects in a size-2 prevalent colocations are connected by a solid line. Once this done, an undirected graph is constructed, of which each vertex is a spatial object and the two vertices connected by a straight line is just a size-2 prevalent colocation. We obtain all maximal cliques from the undirected graph based on the Bron-Kerbosch algrithm, and regard them as the candidate maximal colocations;

Step 4 (filtering prevalent maximal fuzzy colocations): Filter the final maximal fuzzy colocations from long to short by the size of candidates. The filtering process for each candidate is as follows: first, construct its fuzzy instance tree based on the FNR$_a$-table and the clique verification approach; second, obtain its fuzzy table instance from the fuzzy instance tree and calculate its fuzzy participation index; third, if its fuzzy participation index is no less than *min_fprev*, it will be reserved as a maximal fuzzy colocation; otherwise, it will be supplanted by its subsets.

5. Experiments

This section conducts experiments of the MFCPM algorithm on real datasets, which concludes 31 species plants with 336 instances in the Three Parallel Rivers of Yunnan Protected Area. The 31 features were denoted by A to Z and a to e in our experiments. Besides MFCPM, the SGCT-K algorithm is the only one that mine maximal prevalent colocations with the proximity level between instances consideration [5]. Both of the two algorithms adopt the SGCT frame given in [4]. The difference of them is that the prevalence measure of the former is FPI while of the latter is the KDE-based prevalence index (PI-K). As the PI-K in SGCT-K is much less than the FPI in MFCPM, we cannot set a definite prevalence index threshold for the two algorithms in the experiments. The algorithms are coded and compiled by Python in the experiments and execute the programs on the Windows 7 operating system with 8 GB memory, 3.4 GHz main frequency and a Intel core i7-6700 processor.

We normalize the real datasets into a 2000 × 2000 space, and define the membership function of the MFCPM algorithm as following:

$$\mu(d) = \begin{cases} 1 & d \leq a \\ -\dfrac{(d-a)^2}{(b-a)^2} + 1 & a < d \leq b \\ 0 & d > b \end{cases} \tag{6}$$

where, *a* and *b* are the arguments to the membership function, *d* represents the Euclidean distance between instances. The parameter *b* in MFCPM and the distance threshold in SGCT-K have similar meanings.

We set $a = 20$, $b = 230$, $\alpha = 0$, min_fprev = 0.3 in MFCPM, and distance threshold is 230, prevalence threshold is 0.025 in SGCT-K. Table 2 lists partial mining results of the two algorithms. It can be seen that is the PI_K is much less than FPI, which is very different from the classic co-location mining with a prevalence index interval [0,1]. Figure 3 show the running time of MFCPM when min_fprev take 0.2 and 0.3 respectively. We can observe that the program executes very fast when min_fprev is

0.3, because it can only produce no more than 150 maximal prevalent co-locations with the size no less than 3 and no more than 5, while it can generate no more than 560 maximal prevalent co-locations with the size no less than 3 and no more than 7 when min_*fprev* is 0.2. The larger the number of results, the higher the size, the more time the algorithm consumes.

Table 2. partial results of the two algorithms.

Size	Maximal prevalent co-locations	FPI (MFCPM)	PI_K (SGCT-K)
Size-5	AJLZc	0.3467	0.0327
	AHJLZ	0.304	0.0267
Size-4	AKLc	0.3759	0.0401
	ALbc	0.3073	0.028
Size-3	ABX	0.3607	0.0257
	BSX	0.3795	0.0624
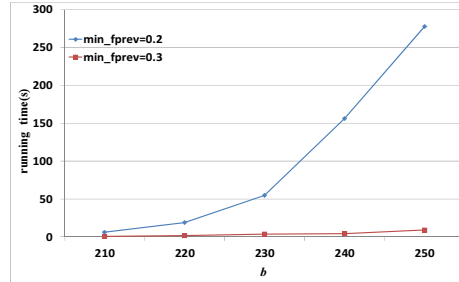
Figure 3. the efficiency of MFCPM

6. Conclusions

We proposed the MFCPM algorithm for mining maximal fuzzy prevalent colocation patterns. MFCPM produces the maximal prevalent colocations from long to short size candidates based on the fuzzy neighborhood relationship(FNR). The candidate maximal colocations are obtained from the undirected graph consisting of the size-2 maximal prevalent colocations, and the table instances of a candidate colocation is generated by its instance tree. Experiments show that the MFCPM algorithm performs good performance.

Acknowledgments

References

[1] Y. Huang, S. Shekhar, H. Xiong, Discovering colocation patterns from spatial data sets: a general approach, IEEE Educational Activities Department , 2004 , 16 (12) :1472-1485.
[2] L. Wang, L. Zhou, J. Lu, et al. An order-clique-based approach for mining maximal co-locations[J]. Information Sciences, 2009, 179(19):3370-3382.
[3] J. Yoo, M. Bow. Mining Maximal Co-located Event Sets[C]. Pacific-asia Conference on Advances in Knowledge Discovery & Data Mining. Springer-Verlag, 2011:351-362.
[4] X. Yao, L. Peng, L. Yang, et al. A fast space-saving algorithm for maximal co-location pattern mining[J]. Expert Systems with Applications, 2016, 63: 310-323.
[5] X. Yao, L. Peng, L. Yang, et al. A co-location pattern-mining algorithm with a density-weighted distance thresholding consideration[J]. Information Sciences, 2017, 396:144-161.

[6] M. Wang, L. Wang, L. Zhao. Spatial Co-location Pattern Mining Based on Fuzzy neighbor relationship. Journal of Information Science & Engineering, 2019, 35(6).

[7] S. Shekhar,Y. Huang. Discovering Spatial Co-location Patterns: A Summary of Results[C]. Proc. The 7th International Symposium on Advances in Spatial and Temporal Databases(SSTD), Heidelberg, Springer, 2001: 236-256.

[8] J. Yoo, S. Shekhar, M. Celik. A join-less approach for colocation pattern mining: a summary of results, IEEE International Conference on Data Mining. IEEE, 2005:813-816.

[9] J. Yoo, S. Shekhar, J. Smith, et al. A partial join approach for mining co-location patterns[C]. Proc. the 12th annual ACP international workshop on Geographic information systems, New York, Washington DC, USA, ACP Press, 2004: 241-249.

[10] L. Wang, Y. Bao, J. Lu, J. Yip, A new join-less approach for co-location pattern mining, IEEE International Conference on Computer and Information Technology. IEEE, 2008:197-202.

[11] L. Wang, Y. Bao, Z. Lu, Efficient discovery of spatial co-location patterns using the iCPI-tree, The Open Information Systems Journal, 2009, 3(1):69-80.

[12] L. Wang, X. Bao, L. Zhou, Redundancy reduction for prevalent co-location patterns, IEEE Transactions on Knowledge & Data Engineering, 2018, 30(1):142-155.

[13] L. Wang, X. Bao, H. Chen, Effective lossless condensed representation and discovery of spatial co-location patterns, Information Sciences, 2018,436: 197-213.

[14] J. Yoo, Boulware, D. and Kimmey, A Parallel Spatial Co-location Mining Algorithm Based on MapReduce. IEEE International Congress on Big Data, 2014:25-31.

[15] P. Yang, L. Wang , X. Wang, A Parallel Spatial Colocation Pattern Mining Approach Based on Ordered Clique Growth, International Conference on Database Systems for Advanced Applications, 2018:734-742.

[16] Z. Ouyang, L. Wang, P. Wu, Spatial co-location pattern discovery from fuzzy objects, International Journal on Artificial Intelligence Tools, International Journal on Artificial Intelligence Tools, 2017, 26(02): 1750003.

[17] M. Wang, Y. Chen, L.He, Y. Wu. Spatial Colocation Pattern Mining based on improved density peak clustering and fuzzy neighbor relationship. Mathematical Biosciences and Engineering, 2021, 18(6): 8223-8244.

[18] M. Wang, L. Wang, L. Zhou. Spatial Colocation Pattern Mining with the Maximum Membership Threshold[M]//Fuzzy Systems and Data Mining V. IOS Press, 2019: 1092-1100.

[19] M. Wang, L. Wang, Y. Qian, et al. Incremental mining of spatial co-location Patterns based on the fuzzy neighborhood relationship[M]//Fuzzy Systems and Data Mining V. IOS Press, 2019: 652-660.

Investigation of the Educational Practice of Normal College Students Based on the "Double Tutor System"

Lanyan QIN[a], Jisheng HE[a], Yuehong FU[b] and Fangping LI[1, b]

a Xiangnan University, Chenzhou, Hunan Province, 423000, China
b Xiangnan Middle School, Chenzhou City, Hunan Province, 423000, China

Abstract. In order to improve the training effectiveness of normal students, Xiangnan University actively explored the "double tutor" mode of joint training of normal students by college teachers and primary and secondary school teachers, providing joint guidance for normal students in educational probation, educational practice and other processes. In order to understand the current situation of normal students' educational practice under the "double tutor" mode, an investigation was carried out through questionnaires and interviews. The results showed that normal students generally benefited a lot from the "double tutor" guidance mode. At the same time, there were also problems such as insufficient preparation for educational practice and the narrowness of guidance content. Considering the training of normal students in the future, it was necessary to further clarify the responsibility of double tutors, pay attention to the cultivation of students' professional and practical skills, and promote the further reform and innovation of normal education in colleges.

Keywords. Double tutor, normal students, educational practice, questionnaire

1. Introduction

As reflective practitioners, teachers realized their professional development in the process of studying their own experience and improving education and teaching behaviors. The traditional training mode of normal students focused on theoretical teaching, far from the real educational environment, which made it difficult for normal students to be quickly competent for the teaching work of primary and secondary schools after graduation. In order to solve this problem, Xiangnan University actively explored the "double tutor system" training mode for normal college students to enhance the practical knowledge and effectively improving their practical application ability through the joint training of students by colleges and primary and secondary schools, realizing the seamless connection between normal college education and primary and secondary education. With much achievements after several years of exploration and practice, the "double tutor" model also met some development difficulties. For example, the "double tutor" system has shown that the mentoring

process in many universities is a mere formality[1]. many external tutors are busy with daily work and lack of theoretical thinking and research on teaching[2],and so on.

2. Definition of "Double Tutor System"

The so-called "double tutor" training mode mainly referred to the joint cultivation mechanism of normal students via multi-level guidance from not only professional teachers in colleges but also front-line teachers in primary and secondary schools. Realistic and vivid practical knowledge was brought to normal students by primary and secondary school teachers. The open idea and inquiry was brought by college teachers, helping normal students to realize the unity of knowledge and practice. For normal students, not only professional guidance of college teachers but also practical guidance of grass-roots teachers could be obtained.

As a public comprehensive full-time ordinary undergraduate university, Xiangnan University was a local university with a total of 46 undergraduate majors, among which there were 9 normal majors, which covered the main disciplines of primary and secondary school courses.

The cooperation between Xiangnan University and primary and secondary schools was mainly carried out through teaching,   practice, teaching and research, evaluation and so on which were all cooperative. In terms of the stages and processes of the normal students training, both on-campus and off-campus tutors participated in the normal students training throughout the four years with different emphasis in each academic year. In the freshman year, the on-campus tutor focused on the guidance of college career planning, and the off-campus tutor focused on educational probation to let students "see middle schools". In the sophomore year, the on-campus tutor focused on professional learning guidance, and the off-campus tutor focused on guiding students to carry out educational research. In the third year of college, the on-campus tutors focused on career planning and teaching skills guidance, and the off-campus tutor focused on educational exercises to let students "learn by doing in middle schools". In the senior stage, both on-campus and off-campus tutors focused on employment and educational practice guidance.

Guiding objectives, tasks, contents and forms of two tutors were also different. College teachers mainly guided students to carry out professional learning and academic Q & A. Thus, forming a multi-level three-dimensional education and guidance system for students whose comprehensive quality could be improved could made them gradually master relevant theoretical knowledge and skills of basic education. Primary and secondary school teachers regularly participated in professional teaching activities. Thus, students could gradually understand basic education management, primary and secondary school students' characteristics and other related knowledge. Through the necessary guidance of educational practice, students were guided to gradually apply the professional theoretical knowledge which have learned in practical teaching. Meanwhile, targeted feedback was used to guide students to improve, forming an effective mode of joint training of normal students by colleges as well as primary and secondary schools (Figure 1).
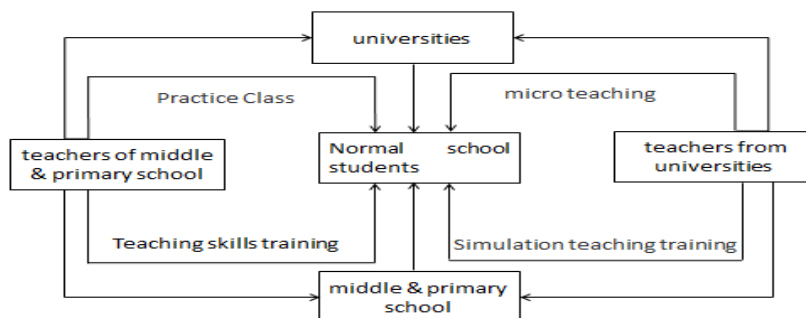
Figure 1. Double tutor training mode

As a comprehensive practical process of qualified teachers training in primary and secondary schools, educational practice was the only way to the educational career for normal students. It was also the beginning of the teaching profession experience for most normal students. It was also one of the important ways to improve the quality and skills of normal students.The normal majors of Xiangnan University have broken through the construction of the traditional and single education practice base, further strengthened the cooperation with primary and secondary schools, fully explored and expanded their respective advantages and functions of colleges, middle and primary schools. The "double tutor" model was adopted to guide students' education practice, undertaking the education responsibility together.

In order to understand the practice situation and effect of normal students under the guidance of the "dual tutor system", improve the practice quality, enhance the sense of acquisition of normal interns, and promote the growth of interns, we investigated the practice of normal students in Xiangnan University by a questionnaire survey and interviews.

3. Research design: survey tools, methods and main contents

In this survey, questions were sent to interns by links in Questionnaire Star which were filled anonymously in the second semester of 2021. In this semester, there were more than 900 normal interns participating in educational practice in Xiangnan University. There were 702 questionnaires accounting for 78% of interns, covering all normal education involved majors. There were 22 questions in the questionnaire, which was divided into two parts. The first part was the basic information of interns, including gender, major, practice way and practice length. The second part was the detailed investigation of interns in the practice school, including the practice stage, practice teaching materials, the number of practice teaching hours, class hours, the guidance methods of instructors and university team teachers for interns and practice effects. The question types included single choice, multiple choice and subjective questions, which could comprehensively and effectively demonstrate the practice status of intern students.

At the same time, the interview method was used to investigate and interview teachers who led the normal students of various majors in the college, instructors of the practice school and interns. In the interviews, there were 20 normal students and 10 on-campus and off-campus practice instructors, among which there were 5 instructors

in the practice base and 5 college practice instructors. In total, there were 30 person times.

4. Statistical results and analysis

4.1. The unbalanced gender ratio of normal students

From the perspective of gender, the proportion of male and female intern students in normal colleges was unbalanced. The number of female students far exceeded that of male students which only accounted for 13.46% of the total. From the perspective of disciplines, the number of students with dominant subjects such as Chinese, mathematics and foreign languages was significantly larger than that of other disciplines, in consistent with the situation of enrollment and employment.

4.2. Strong concentration of practice

The data showed that about 85.58% of the intern students   adopted the centralized practice according to the college arrangement. Scattered internship, post internship and independent internship by students' own contact with the school   were few. Due to the influence of the practice base, the practice section was mainly junior high school. 68.27% of the students participated in the junior high school practice, and 25% of the interns were in senior high school. No students participated in the   primary school practice.

4.3. Students' good attitudes and attention to the practice

First of all, most interns recognized the importance of the practice. The proportions of students who considered the practice very important and important were 69.23% and 25%, respectively. Secondly, during the practice, interns with the class attendance above 20 and 16-20 whose corresponding proportions were 53.85% and 18.27%, respectively, constituted a majority. Thirdly, the mutual communication initiated by both interns and instructors constituted a majority with the proportion of 54.46%. And only 1.98% of the students never communicated with instructors forwardly during the practice. In addition, 70.19% of the interns' teaching design asked for the guidance of the instructors and finished the revision of the teaching plan before class. After class, they reflected and explored teaching methods, demonstrating a strong autonomy and reflective ability as well as the active learning spirit of contemporary college students.

4.4. The appropriate practice length

In order to strengthen the construction of teachers' team from the source, the Ministry of Education issued the "opinions on vigorously promoting the practice and teaching support work of normal students" in 2007, which clearly required senior normal students to go to primary and secondary schools for educational practice not less than one semester. 96.8% of the students in our college spent one semester in the practice school. 2.6% of students' practice lasted more than one semester. From the perspective of time length, 74.04% of the students agreed with the just right time arrangement.

Only 11.54% of the students regraded it as too long with tiredness. Another 14.42% of the students thought that the practice time was too short to get fully practiced.

4.5. Double tutors jointly promoted the growth of interns

In terms of guidance methods, college team teachers and the practice school instructors worked together to promote the growth of normal interns. 66.35% of the interns received the joint guidance of our teachers of our school and the instructors of the internship school during the internship (Figure 2).
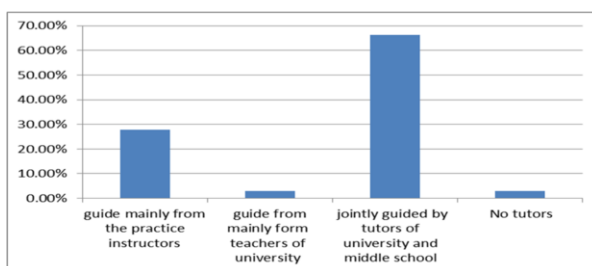
Figure 2. Guidance from double tutors

In terms of guidance methods, there were differences between practice instructors and college instructors. The diversity of the guidance methods of the practice instructors was strong. Adopting the onsite teaching, 37.5% of instructors gave comprehensive guidance in the selection of teaching methods, the application of teaching strategies, the grasping of knowledge points, and the practical arrangement of teaching content (Figure 3). However, college teachers mainly gave guidance of lectures and mutual evaluation within the group.
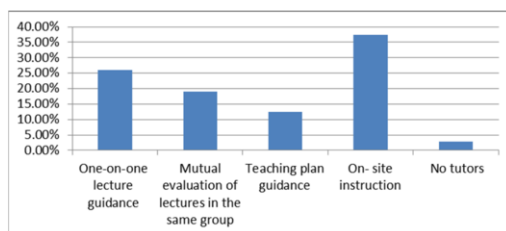
Figure 3. The guidance methods of teachers in practice schools

Through the practice, interns benefited a lot. 85.58% of the students thought that the practice enriched their professional knowledge and teaching experience. 81.73% improved their professional awareness and professional emotion. 68.27% of the students agreed that they had gained experience in getting along with students. And 48.08% of the students clarified their career directions. In this practice, 75.96% of the students thought that the help from the practice tutor was the largest.

5. Existing problems

5.1 Insufficient preparation for the practice

In the open questions which asked for the suggestions for improvement suggestions, nearly 50% of the students suggested the in-time information of the practice which guaranteed the earlier preparation. 56.73% of the students wanted to be trained before the practice, appropriately. Although students who entered the senior grades realized the beginning of the practice as soon as the autumn semester started. Most students didn't clearly know the teaching materials in the practice period because of the unconfirmed practice whether in junior or senior high school, which has become one of the obstacles for interns to quickly get into the state. In addition, the questionnaire demonstrated that 58% of the students looked forward to the educational practice in advance. However, 20% had no feeling and 22% even didn't expect the educational practice. The interview demonstrated that boys were mostly unwilling to engage in the education industry because of the feeling of no future. Girls had a relatively high enthusiasm for the education industry, and thus gained relatively more through educational practice.

5.2 The deficiency of the guidance

On the one hand, the centralized practice method facilitated the overall management of interns by the college and the timely grasp of the situation of interns, thus ensuring the practice effect of interns to a certain extent. But on the other hand, it put some pressure on the practice school. Each practice school needed to receive more than 30 interns students. Middle school teachers, especially high school teachers themselves, had great teaching pressure and did not have much time and energy to guide students. In order to reduce the pressure of instructors, practice schools also had mixed conditions in the allocation of instructors and teachers. Considering the improvement suggestions, about 45% of interns mentioned that they expected experienced teachers to be sent as instructors by the school.

Secondly, in terms of guidance content, the instructors of practice schools guided students more from the perspective of discipline and professional knowledge, such as class teacher work, class management and so on. After the practice, all colleges and departments evaluated and graded the educational practice, mainly according to the practice report and the back talk course after the practice. However, the back talk process was often a mere formality with no obvious effect. In the survey, 64.42% of the students thought that they met difficulties in class management. 59.62% also felt thorny in classroom discipline management (Figure 4), expecting more guidance and help in these aspects.
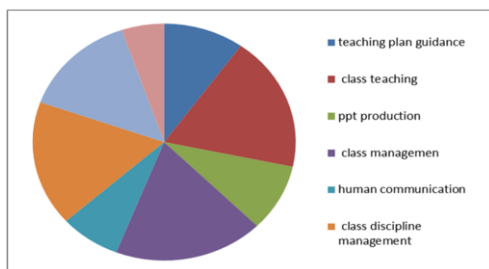
Figure 4. Difficulties encountered by normal students in the practice

5.3. Few practice opportunity for normal students

In the educational practice, 44.23% of interns had 6 to 10 classes, and 32.69% had less than 5 classes. There were many reasons for this situation. From the perspective of practice schools, it reflected the current high teaching pressure situation of high school teachers, because the instructors didn't dare to risk the interns on the podium. Additionally, insufficient preparation of interns, poor communication between the college and the practice school, and few class hours of the discipline itself were also the reasons.

6. Recommendations

6.1 Making preparations before the practice

Before the practice, colleges should carry out the discipline training of primary and secondary schools for students in a planned way. The grasping of the textbook version and knowledge system used by the practice school could facilitate interns to quickly get into the practice state. Meanwhile, the connection between each practice stage should be strengthened. Personal growth files for normal students' educational probation and educational practice should be formulated, consisting of three parts, namely, the description of the whole practice process and the procedure introduction, the practice process and the reflection of normal students' educational practice, preparing for their participation in educational practice in the future, wherein the second part should include the records of class attendance and evaluation, the work log of the class teacher, the teaching plan, the final practice summary and practice evaluation. With the practice manual, the real-time feedback and communication in the process of educational probation and practice should be combined with the network to promote the development of normal students' practical ability.

6.2 To enhance the instructor's sense of responsibility

College and primary and secondary school instructors should enhance their sense of responsibility and communicate more frequently with interns to find and solve problems in the process of education in time. Professional instructors in colleges and primary and secondary school teachers should clarify their responsibilities. College instructors mainly provide necessary teaching guidance for normal students in terms of ideology and morality, professional basic knowledge, teaching theory, teaching skills,

etc., promoting the improvement of their abilities and further enrichment of their professional knowledge. Primary and secondary school teachers mainly guide normal students in the training of teaching skills and the transformation of teaching roles. They organize normal students to carry out necessary practical teaching and cultivate students' professional and practical skills. In a word, both college instructors and primary and secondary school instructors should be responsible for the guidance of normal students in terms of discipline and professional knowledge, class management and so on. Through the guidance of educational practice, students who could be evaluated according to real practical teaching could be guided to apply the professional theoretical knowledge learned in practical teaching and improve with targeted feedback. Thus, a multi-level and three-dimensional education and guidance system could be formed to improve students' comprehensive quality.

6.3 The perfect carrying out of the "double tutor" educational practice management system

The operation of educational practice could not be separated from the guarantee of the perfect system These systems include the working system in the whole process, the guiding teacher working system, and the evaluation index system after the educational practice. The responsibility system of educational instructors should be implemented. The post responsibility system of on-campus and off-campus instructors should be established. The role orientation, responsibility requirements, work content, reward and punishment measures of on-campus and off-campus instructors should be clarified to form the post responsibility system. The work responsibility consciousness of on-campus and off-campus instructors should be strengthened. Meanwhile, new educational management methods should be considered and used to finally realize the "practice oriented and student-centered" educational concept.

6.4 To establish various communication platforms

In view of the practice situation of normal students in the practice school, relying on the network, a multi-party communication platform could be established for the timely feedback. The school could issue the practice content and the goal of normal students on the network platform. Normal students could obtain the latest information in time, complete learning tasks and achieve learning goals. The school could grade students according to their performance. Meanwhile, according to students' real practice situation, tasks could be adjusted in time to achieve humanized communication. Students could also put forward problems and questions to be solved through the platform and get timely guidance and response from teachers. Instructors should reflect the practice situation of normal students on this multi-party communication platform as more as possible giving normal students more suggestions, keeping contact with and communicate with colleges to ensure the high efficiency and quality of normal students' practice.

6.5 Study from international experience

Developed countries have accumulated rich experience in guaranteeing the quality of teachers under the "double tutor" system, and have evolved a scientific and rich model of teacher training based on it.

In many universities in the United States, students in normal education practice on the basis of "double tutor" cooperative teaching. In this mode, colleges and universities have established a broader partnership with their surrounding primary and secondary schools[3] .a project organization operation. "Direct school training" is the normal education mode implemented by the British Ministry of Education nationwide, which has been Implemented nearly ten years. In this mode, the numbers of primary and secondary schools form a teaching school alliance, and then look for universities to cooperate; All the follow-up work is carried out by the Teaching School Alliance. Normal university students will complete practical training in schools within the Alliance and obtain corresponding teacher certificates and job opportunities[4]. Singapore's "three mentors" collaboration model: create an internship mentor group. In order to ensure the quality of teacher education, the Singapore government developed the "double tutor" system into the multi-tutor system. Normal university students will receive guidance from multiple tutors when participating in educational practice[5]. In addition to the "double tutor" system, school coordination tutors are added in this training mode. They come from the primary and secondary schools where normal university students practice and are responsible for organization, management and quality supervision[6].

Acknowledgements

References

[1] Zhang Xingfeng, Zhang Nan, Hou Shenyan. Construction of "Double Tutor" System for Normal University Students from the perspective of professional certification [J] Heilongjiang Education (Higher Education Research and Evaluation), 2020(11):55-57.

[2] Wang Nianli. Effects and problems of implementing "double tutor" system in educational courses [J]. Journal of Shijiazhuang University, 2020, 22(04):55-59.

[3] Liang Huifang, Research on cooperative Teaching Practice Model in The United States [D] Central China Normal University, 2018.

[4] Zhang Xiudan, Liao yuanxi, Research and Enlightenment of the "School Direct Training" project of Pre-service Teachers in Britain [J] Journal of Hainan Normal University (social science edition), 2018, 31(06):76-80.

[5] Wang Xiaofang, Zhou Jun. Research on the quality assurance mechanism of educational practice for normal students in Singapore,[J] Comparative Education Research, 2019,41(05):76-82.

[6] Gao Hui, Wang Zhe, Liu Lifeng, Li Yingji. Construction of "double integration and double tutor" talent cultivation mode for pre-school education under the background of professional certification: a case study of jilin normal university of engineering and technology [J] Vocational and Technical Education, 2018, 39(35):10-13.

Research on the Transformation of Enterprise Financial Personnel in the Era of Big Data

Yuan XIAO[a] and Xuan CHEN[1, b]

ª School of Economic and Management, Xiangnan University, Chenzhou, China
ᵇ School of Foreign Languages, Xiangnan University, Chenzhou, China

Abstract. The advent of the big data era is both an opportunity and a challenge for financial personnel. It has changed the accounting process and strengthened the function of accounting posts to a certain extent. Financial transformation has become an important topic for enterprises to improve their management level and competitiveness. It is necessary to explore the trend and path of financial transformation. Taking the big data application of Handu Group as an example, this paper analyzes the impact on financial organizations and financial personnel, and provides a reference for the transformation of enterprise's financial personnel. Big data will cause changes in organizational structure and personnel structure. Accountants should not only change their ideas, but also constantly improve their work quality and efficiency with the help of informatization. Enterprises should promote the transformation and development of accountants to meet the new requirements of enterprise's financial management in the context of cloud computing. Financial personnel of enterprises should comply with the development of the trend of the times and make full use of various learning channels to supplement the skill requirements of big data and cloud background for financial work.

Keywords. Big data, financial staff, transformation

1.Introduction

Big data is developed on the basis of communication technology. In recent years, with the widespread popularization of network technology, the concept of big data has been well known by all sectors of society. Big data, also called massive amounts of data, is made up of many types of quantity huge, complicated structure, data structure of data collection, the amount of data involved are too large to through the current mainstream software tools, in a reasonable time to capture, manage, process, and through finishing can become enterprise management and decision-making information. With the advent of the digital era, enterprises begin to pay attention to the acquisition and integration of basic information, and constantly increase the analysis and application of financial big

[1] Corresponding Author, Xuan Chen, School of Foreign Languages, Xiangnan University, Chenzhou, China; Email: 418168938@qq.com.

data. In the era of big data, financial work is also facing both opportunities and challenges.[1] In order to ensure that enterprises always occupy a dominant position in the market competition, it is necessary for the financial and accounting departments to keep pace with the development of The Times, deeply understand the essential characteristics of big data, actively change the work management mode, effectively improve the internal fund management level of enterprises, so as to speed up the transformation of financial functions to their extended functions. According to statistics, there are about 40 million financial employees at present. By 2025, automation and a new division of labor between humans and machines will disrupt 85 million jobs across 15 industries worldwide. With automation and digitization, employment demand for skills such as data entry, accounting and administrative services is decreasing (report on Future Employment 2020).

2. The Impact of Big Data on Financial Work

2.1 The form of financial report shall be transformed from post hoc report to real-time report

At present, accounting personnel of enterprises usually prepare financial reports after the completion of their production and business operations, such as the annual financial report is completed within 4 months of the next year, which has a certain negative impact on the timeliness and efficiency of accounting information. Driven by the development of science and technology, people gradually realize the importance of real-time financial reporting, and the era of big data is the basic guarantee for real-time financial reporting. Based on the background of big data era, the construction of real-time financial reporting system of enterprises includes but is not limited to: the establishment of a unique central database of enterprises, and timely update the business data of economic activities in the central database. In order to better share and synchronize the central database and external data of the enterprise, the enterprise should also build and improve the enterprise real-time financial reporting system website, to achieve the effective connection between the central database of the enterprise and the external Internet.

2.2 The working mode of accounting changes from reflecting the past to predicting the future

For a long time, the basic function of corporate accounting is to reflect and supervise, and forecasting is just an extended function. However, in the era of big data, accounting personnel can make full use of the data advantages of big data to predict the future financial risks of enterprises and take targeted countermeasures. At the same time, big data can change the way accountants work and give full play to the forward-looking role in the development of enterprises. In this process, enterprise accountants collect, transfer and store a large amount of information, and gradually change the focus of accounting work. Through the analysis and mining of accounting data, enterprises can provide predictive information, so as to lay the foundation for making reasonable decisions. [2][3]

2.3 Financial management concept from single to comprehensive transformation

In traditional mode, the only enterprise financial management work in the field of corporate finance, financial information users have largely focused on the related personnel of the enterprise, such as enterprise owners, managers, creditors, etc., in the financial report users, the need for final financial data (typically a financial report) to meet the need of secondary processing before they can read their financial information, And take this as the decision basis of investment and financing. In the era of big data, financial management should involve the formulation of production plans, product sales, research and development, human resources and other fields. From the enterprise comprehensive budget preparation starting point - sales budget, production, inventory, manpower, the essence of enterprise management into the financial management work. In short, the core work of enterprise financial management should be to analyze, collect and manage the data involved in enterprise production and operation. In the era of big data, the scope of enterprise financial management has been expanded, also known as "comprehensive financial management".[4]

3. Case analysis of big data application in Handu Group

3.1 A Brief Introduction of Handu Group

Shangdong Handu E-Commerce Group Co., Ltd. (hereinafter referred to as "Handu Group") was founded in 2006. It is an Internet e-commerce group with clothing, home textiles, cosmetics, shoes and bags, sports and other products as its main business scope. It has more than 70 brand clusters, and is favored by the majority of consumers with the characteristics of "many styles, fast update and high cost performance". Headquartered in Jinan high tech Zone, Shandong Province, the company has more than 40 departments, including supply chain center, warehousing center, marketing center, information center, product research and development center, vision center, and Handu University, with more than 2600 employees. From 2012 to 2018, it ranked first in the industry for seven consecutive years. In 2020, it became the first brand in the "Tmall" women's clothing category, and has now become one of China's largest Internet ecological operation brand .[5]

3.2 Solutions of big data

Handu Group will launch thousands of products every quarter with tens of thousands of different sizes and colors. The fast updating of clothing styles and a large number of brands make it difficult to allocate enterprise resources and manage the finance. The poor information transmission between departments also puts pressure on the Group's timely financial prediction and analysis.

Before using big data to carry out financial management, Handu Group carried out transactions on the e-commerce platform, but its accounting records were mainly manual bookkeeping. The data used in financial analysis were mainly clothing sales and prices. Due to the low efficiency, time-consuming and high error rate of manual bookkeeping, it could not adapt to the increasing competitive pressure of the e-commerce industry and the demand of frequent   update of the product. Therefore,

Handu Group has successively adopted a series of digital systems, such as OA (office automation) office system, Kingdee financial system, Enterprise Resource Planning (ERP) system, Warehouse Management System, Business Intelligence (BI) system, Supplier Relationship Management (SRM) system, to replace the original manual accounting method and realize the digitization of the Group information. In addition, combined with the characteristics of its own clothing products and business processes, it has independently developed a sample clothing review system, commodity release system, commodity clearance management system and other big data analysis systems that adapt to the Group's operating environment. Through these information systems, Handu Group has realized the digital record of the whole operation process, including product design, supplier selection, production, warehousing, delivery, inventory management, product marketing and consumer evaluation. Handu Group adopted big data technology to improve the efficiency of the Group's financial management. [6]

The big data analysis system of Handu Group is mainly composed of three modules, [7] which are the Business Intelligence (BI) responsible for data collection and label management, the Business Analyst (BA) responsible for data classification and storage, algorithm and analysis, and the artificial Intelligence Module (AI) responsible for visualizing data information to assist financial and production decisions.

After applying big data for analysis, in addition to financial information, the Group also added some non-financial information, such as competitor's sales information, into the influencing factors of budget analysis. At the same time, the information integrated by different data sources has also greatly increased the amount of information and data of the Group. The Group can obtain   previously undiscovered data trends. The increase of the type and quantity of input data can make the financial budget of enterprises more suitable for the business environment, and make the enterprises' profit forecast more reliable. Through the application of big data to assist the budget, the accuracy of sales forecast of Handu Group increased from 38% in 2013 to 72% in 2017, the budget of gross profit margin and actual variance rate decreased by 5%, and the budget of net profit margin and actual variance rate decreased by 6%.

At the same time, the function of big data system to update enterprise operation data in real time also strengthens the Group's budget process control. Although the budget is formulated by the financial department, it is the front-line business personnel who can really find the deviation between the budget and the actual effect. Under the traditional budget mode, there will be a long delay when the deviation in the implementation of the budget is transferred from the business department to the financial analysis department However, the Group introduced the big data system and integrated the enterprise's information system. The actual budget implementation data of the front-line business departments will be directly fed back to big data, and the financial personnel can obtain the operation information of the business departments in real time. Through the risk early-warning model, the system will warn the financial department when the data deviates greatly from the budget, and further trace and analyze the reasons for the deviation. Compared with the traditional budget management mode, the budget management supported by big data can better control the budget process. At the same time, it is easier to find and improve the causes of problems in the Group's operation.

After the introduction of the big data system, the Group's financial data and business data have been integrated. The Group can incorporate some indicators of business process specification into the employee's performance appraisal. The system will record the employee's non-compliance operations and link them with the

employee's bonus. This can make the Group's business process more standardized, thus making the budget assumptions set by the Group more reliable.

3.3 Common problems of accounting staff in the era of big data

Through the above big data on the changes in financial work, combined with the current work of financial staff feedback problems, this paper is summarized as follows.

3.3.1 Lack of professional skills

Professional skills are not here refers to the operational skills of accounting treatment, but in the era of big data, through the Python, RPA financial development and financial application development and application of robots on the data of financial information for financial analysis and the application of smart financial and visualization, is the application of specific scenarios digital ability to work. And the existing financial personnel, the mastery of these abilities is relatively weak. There are quite a number of accounting personnel is also adapted to the traditional manual accounting treatment in the past, some accounting personnel only mastered the computerized accounting software operation, such as business module is familiar with accounting software, but if used in the enterprise financial database programming language to extract the required financial data, or more difficult, Only through the low efficiency of the "carpet" search, reduce the processing efficiency of financial work, but also difficult to ensure the accuracy and effectiveness of financial data.[8][9]

3.3.2 Unable to adapt to the transformation of financial functions

From the analysis of the first part of this paper, we can see that the function of accounting will have a greater degree of change. In the past, the two basic functions of accounting were accounting and supervision, while forecasting economic prospects, participating in economic decision-making and evaluating business performance were the extended functions of accounting.[10] At present, the majority of enterprises to accounting post of financial personnel requirements still stay in the basic economic business can deal with the preparation of four tables a note (that is, balance sheet, income statement, cash flow statement, owner's equity changes and notes to financial statements), reflects the accounting of the past has been the reflection of business. In the context of big data cloud computing, accounting should not only reflect the past, but also reflect the value of its work by predicting the future. However, at present, many financial personnel do not have such awareness. They generally believe that predicting prospects, participating in enterprise management decisions and evaluating performance and other behaviors do not belong to the scope of responsibility of accounting. They still think that this belongs to the management or other departments, which is not conducive to the development of accounting work in the future.[11]

4. Conclusions and Suggestions

4.1 Conclusions

To sum up, in the context of cloud computing, the transformation of financial accounting personnel in manufacturing enterprises should be based on the actual development of enterprises and formulate corresponding strategic planning according to the development requirements of enterprises at different stages. For enterprise managers, they should have certain forward-looking thinking and have a correct understanding of the transformation of accounting personnel. Accounting personnel should not only change their ideas, but also constantly improve their work quality and efficiency by means of information technology, so as to promote the transformation and development of accounting personnel from the perspective of innovation, so as to adapt to the new requirements of enterprise financial management under the background of cloud computing.

4.2 Some suggestions on the transformation of financial personnel

Using the technology of artificial intelligence measurement, USES the advanced work force and algorithm (extended) accounting measurement ability, has is the direction of the current development of financial work, Therefore, in this process, financial personnel must carry out transformation.[12]

4.2.1 Supplement knowledge and skills with abundant online teaching resources

Because of the epidemic, online teaching resources are now abundant. For example, open MOOC, learning platform and online teaching resources developed by some enterprises, such as wangzhongwang. On-the-job financial personnel can use their spare time to learn financial development courses on the Internet to supplement their required professional knowledge.[13] In the selection of courses, financial personnel can choose different positions in the big data center according to their actual situation, such as big data business post, big data project post, big data sales post, big data RESEARCH and development post, big data management post, big data analysis post, etc., and then carry out targeted complement of knowledge and skills. So as to cultivate professional skills in intelligent fiscal and tax accounting, tax declaration and management services, and develop professional literacy in fiscal and tax sharing, service sharing and financial cloud intelligent technology application.[14]

4.2.2 Actively change the concept of occupation, better adapt to the change of The Times

Changes in the social and economic environment will also pose significant challenges for all professions, especially in these challenging times. Technological progress and social change has great influence on the financial work, financial personnel should face up to big data cloud computing era brings opportunity and challenge, change the traditional ideas, the accounting personnel to clarify the technical innovation, to a certain extent, to strengthen the accounting functions, implement accounting personnel in the current situation has reached a critical period of transformation, which to the

enterprise's own management, Financial budget and other aspects have a huge impact. In the process of accounting personnel transformation, we should not only start from the financial department, but also strengthen the connection with other departments to ensure that accounting functions can be fully implemented in each link of enterprise operation and management. It can be said that as long as the accounting work is integrated into all aspects, the objectivity and comprehensiveness of data information can be guaranteed to the greatest extent. Once divorced from reality, it can not only provide help for enterprise decision-making, but also affect the scientific judgment of financial affairs, and can not find out the problems in time.[15]

Acknowledgements

Reference

[1] Appelbaum D,Kogan A, Vasarhelyi M, et al. Impact of business analytics and enterprise systems on managerial accounting[J].International Journal of Accounting Information Systems, 2017, (25):29-44.
[2] Dr. Ahmad A. Abu-Musa. Auditing E-Business: New Challenges for External Auditors[J].The Journal of American Academy of Business Cambridge, March,2004(41).
[3] Lee C, Kim S & Yeo Y. Proposal of security requirements based on layers and roles for the srandardization of cloud computing security technology[J].Journal of Security Engineering,2013(04):473-488.
[4] Dusenbury R.B, Reimers, J.L & Wheeler, S.W. The audit risk model: an empirical test for conditioned dependenceies among assessed component risks[J].Auditing A Journal of Practice Theory,2011(103):1080-1106.
[5] Sun Bo. The Challenges of Human Resource Management System in the Digital Era --The Case Analysis on the Digital Transformation of HANDU[J].Business Economic Review, 2020, Vol.21, No.6: 105-115.
[6] Gaoliang Tian, Hu Chen, Yancong, Sun, Yang Liu. Research on Financial Transformation under the Background of "Great Wisdom Propelling Clouds" [J] Finance and accounting monthly, 2019, (20): 3-7
[7] Juan Peng, Hu Chen, Zexia Wang, Renyu Hu. Digital finance [M] Beijing: Tsinghua University Press, 2020,10.
[8] Jie Cai. Application of Cloud Computing in secure Storage of computer network -- Review Cloud Storage Security: The Cornerstone of Big Data Analytics and Computing[J].China Sciencepaper, 2020, 15(11):81-82.
[9] Chunxia Fan. Explore the strategy of transformation from financial accounting to management accounting under the background of big data[J].Contemporary Economics,2016,(36):74-75.
[10] Jia Zhang. Strategy discussion on promoting enterprise financial management informationization [J].China Journal of Commerce,2014(21) : 92-93.
[11] Chunyan Yu. Exploration of effective implementation of management accounting informatization under financial sharing service [J].China International Business,2018(1):52-53.

[12] Huimin Chen. Research on the application of cloud computing in financial Management informatization [J].Modern Economic Information,2017(1):177-178+180.

[13] Shengxia Yu. The construction idea and path exploration of intelligent finance under the background of cloud computing technology [J].Financial supervision,2020(8):94-98.

[14] Chao Hu, Huaihong Yang. Intelligent financial management and its future development trend[J].Marketing Management Review, 2020,(05):226-227.

[15] Jianrong Tang. Research on application of robot process automation in enterprise Financial sharing center [J].Communication of Finance and Accounting, 2020(12):164-168.

Review of Li-Li Mixture XOR Algorithm

Jie-feng YANG[1,a] , Li-shan HUANG[b] and Cheng-lian LIU[c]

[a] *Department of Science and Technology, Shiyuan College of Nanning Normal University, Nanning 530000, China*

[b] *School of Management, University of Pacific, Nicaragua*

[c] *School of Computer Science, University of Pacific, Nicaragua*

Abstract. RSA is one of the well-known public key cryptography algorithms (asymmetric encryption cryptosystem) , it has been more than 40 years since it was put forward. There are countless literatures on RSA related issues; hot discussion and popularization in academic and industrial circles, it is one of the typical public key cryptosystems. The reliability of RSA algorithm mainly depends on the factorization of large integers mentioned in the principle of RSA algorithm because it is extremely difficult to factorize very large integers. Unfortunately, there is no sufficient way to break the RSA. Due to the low efficiency and decryption speed of RSA computing, many scholars are committed to improving the efficiency of RSA algorithm, Ping Li and Yong Li's algorithm (hereinafter referred to as Li-Li algorithm) is one of the research literature. A hybrid encryption algorithm based on XOR operation proposed by Li-Li has defects, this defect is not easy to detect, this paper will point out the problem and give examples to prove the authors claims.

Keywords. RSA algorithm; XOR operation; Large number decomposition problem

1. Introduction

With the development of information technology, today's society has entered the information age, that is, based on modern communication network and database technology, collect relevant information into the database. However, in the process of information exchange and transmission, it also faces many security risks. Our personal information, computer hardware, software and data have been maliciously or accidentally damaged, tampered with and leaked. In August 2013, the data leakage of YAHOO [1] had caused the information of more than 1 billion users to be leaked; In March 2017, a major data leakage event occurred at AJL[2]. A hacker hacked 4 million 800 thousand related personnel 'data through loopholes, And so on. RSA was one of the

---

[1] Corresponding Author, Jie-feng YANG, Department of Science and Technology, Shiyuan College of Nanning Normal University, Nanning 530000, China, Email: 390037931@qq.com

well-known non dual encrypted techniques. This makes us more aware of the importance of personal information protection. Therefore, in order to better and faster guarantee the transmission of information files, people have developed some better calculation methods for confidential information files. RSA was one of the well-known non dual encrypted techniques.

Table 1 — Related Literatures

Particular year	algorithm	autograph	Cloud app	other
2010		Fang et al.[3]		
2011		Liu and Zhan[4]	Zhang et al. [17]	
		Liu et al.[5]		
2012	Guo and Liu[6]			
2013	Li and Li[7]			
2014	Liu et al. [8]			
2015				Liu et al. [9]
				Wu and Liu[10]
2016				Zhang et al. [11]
2017				Yan et al. [12]
2018	Ye et al. [13]			Zhang et al. [15]
	Fang and Liu[14]			Liu et al. [16]
2019	Liu and Xu[18]		Chen and Liu[19]	
2020	Yang et al. [20]		Zhong et al. [21]	

RSA had a wide range of applications, and its application in digital signatures was like that in documents [3, 4, 5], The discussions on cloud advertising and security were like [17, 19, 21], and the most extensive ones were about the research on the calculation itself, like [6, 7, 8, 13, 14, 18,20]. RSA can also be discussed in conjunction with other fields, such as the contact with Goldbach [9], the application of anonymous express information system [10], the application of internal control of enterprises [11,12], the application of free card bank mobile payment [15], the application of [16] for anonymous complaints, and so on. All show that people are deeply interested in RSA. See Table 1 for details.

2. Review of Li-Li algorithm

The ideas of Li Ping and Li Yong (hereinafter referred to as Li-Li algorithm) [7] are mainly through XOR operation and RSA algorithm [22]. The encryption of key and plaintext makes the speed of information encryption faster, so a hybrid encryption algorithm based on XOR is proposed. In this section, we will introduce the principle of RSA algorithm in sequence, and then introduce the operation idea of Li-Li algorithm, as shown below.

2.1 The of RSA algorithm

RSA is a public key cryptography algorithm. Its name is composed of the initials of the last names of several developers, namely Ron Rivest, Adi Shamir and Leonard Adleman. RSA algorithm uses different encryption keys and decryption keys to encrypt information, which ensures that the information will not be decrypted and disclosed by

others in the process of transmission. However, the efficiency is low and the process of encryption and decryption is slow. Principle of RSA algorithm: According to the elementary number theory, the number obtained by multiplying two prime numbers is used as the public key, it is extremely difficult to decompose this product into the original two prime numbers, that is, the so-called large number decomposition problem. There are many literatures on large number decomposition, but there is no effective method to decompose large numbers. RSA shows its security based on the premise of the difficulty of large number decomposition.

The principle of RSA algorithm is as follows:

step 1. Randomly select two prime numbers p and q ,and calculate

$$n = p * q \tag{1}$$

step 2. Then calculate

$$\varphi(n) \equiv (p-1)(q-1) \tag{2}$$

step 3. Randomly select a public key value e , to satisfy $\gcd(e, \varphi(n)) = 1$, and calculate the value of   as follows

$$e * d \equiv (mod\ \varphi(n)) \tag{3}$$

step 4. A message m is encrypted to obtain ciphertext C , which is calculated as follows

$$C \equiv m^e (mod\ n) \tag{4}$$

step 5. The more the ciphertext C is restored, the following operations are performed

$$m \equiv C^d \ (mod\ n) \tag{5}$$

The order of the above equations from (1) to (5) is the famous RSA algorithm principle. The public key pair parameter is $\{n, e\}$, and the key pair parameter is $\{n, d\}$, according to the principle of RSA algorithm, parameter $\{p, q, \varphi(n), d\}$ is not public, and only n and e are public.

2.2 The Li-Li Algorithm

Based on Li Ping-Li Yong algorithm, it is assumed that Alice, the publisher, encrypts and transmits C_p and C_k to Bob, the receiver, and Bob uses the key given by Alice combined with XOR operation to decrypt and restore C_p and C_k . The specific Li-Li algorithm is shown in Figure 1.

step 1. Alice randomly selects a k value and performs XOR operation on message m and k , as shown in equation (6).

$$C_p = m \oplus k \tag{6}$$

step 2. Use RSA public key e to encrypt its k , see equation (7).

$$C_k = k^e (mod\ n) \tag{7}$$

Then transfer   and   to Bob.

step 3. When Bob receives C_p and C_k from Alice, he first uses RSA key d to obtain the value of   as follows

$$k \equiv (C_k)^d (mod\ n) \tag{8}$$

step 4. After obtaining k , k is used to XOR C_p to restore the content of message m .

$$m = k \oplus C_p \tag{9}$$

$$\text{Alice} \qquad\qquad\qquad\qquad\qquad \text{Bob}$$

1. $C_p = m \oplus k$ 1. $k \equiv (C_k)^d \pmod{n}$

2. $C_k \equiv k^e \pmod{n}$ $\{C_k, \ C_p\}$ 2. $m = k \oplus C_p$
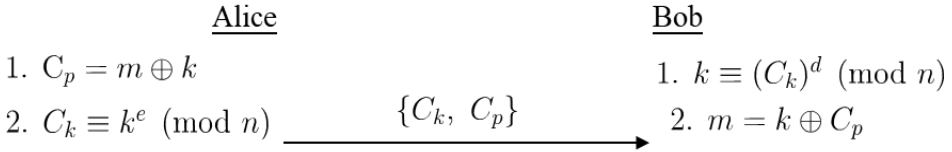
Figure 1. Li-Li algorithm protocol diagram

Equations (6) to (9) are the essence of the Li-Li algorithm.

The beauty of the Li-Li algorithm lies in:

1) In the process of communication between the two sides, the message m is not transmitted. The attacker cannot calculate the message m through the intercepted C_p and C_k. based on this, Alice and Bob do not have to worry about disclosing the content.

2) During transmission, the key values k and d are not present, and it is impossible for an attacker to obtain this value from empty space.

2.3 Data from experimental results

1) Randomly select two prime numbers $p = 27$ and $q = 73$, and calculate $n = 27 * 73 = 1917$.

2) Suppose $e = 29$, and $\varphi(n) = 1872$, because $\gcd(e, \varphi(n)) = 1$, then $d = 581$.

3) Assume that the message is digitized to $m = 70$.

4) Randomly select k value as $k = 79$.

5) Calculate $C_p = 70 \oplus 79 = 9$.

6) Calculate $C_k \equiv 79^{29} \equiv 1921 \pmod{1971}$ and pass C_p and C_k to Bob.

7) Bob calculates the value of k after receiving C_p and C_k.
$k \equiv 1921^{581} \equiv 79 \pmod{1971}$.

8) Calculate the m value again,
$m = 79 \oplus 9 = 70$.

The above is the calculation process and experimental data of Li-Li algorithm.

3. Our comments

Li Ping-Li Yong algorithm proposed a new hybrid encryption algorithm. The security of this algorithm is the same as that of RSA algorithm. When the algorithm communicates with each other and does not transmit information m, the second cannot read m. For RSA algorithm, the initial version uses the Euler function [23] $\varphi(n)$. However, in order to improve computational efficiency while maintaining the same security, in the second version of the RSA algorithm modification [24], has been changed to $\lambda(n)$, as follows

$$\lambda(n) = (p - 1, q - 1) = (26,72) = 936 \qquad\qquad (10)$$

Is there a number y and it is satisfied

$$m^{\varphi(n)} \equiv m^{\lambda(n)} \equiv m^y \equiv 1 \pmod{n} \qquad\qquad (11)$$

It is known from reference [8] that whether there is a more efficient method to solve $y = 36$ as one of the methods to calculate y is our follow-up work.

4. Conclusions

To sum up, whether there is a y for n generated by any prime numbers p and q to meet equation (11) is a problem worthy of discussion, which is not only related to the security of RSA algorithm, but also discussed by number theory or computer algorithm. For solving y, it will be listed as the research direction in the future.

References

[1] Xinhua news agency, the data leakage incident that happened in YAHOO in August 2013, caused more than 1 billion users' information to be leaked, Xinhuanet, http://www.xinhuanet.com/world/2016-12/16/c_129406345.htm, 2016-12-16.

[2] C114 China communications network, shocking 2017 inventory of ten major data leakage incidents, thousands of WeChat official account, http://www.qianjia.com/html/2018-01/12_282375.html, 2018-01-12.

[3] Dejian Fang, Na Wang, Chenglian Liu. An Enhanced RSA-based Partially Blind Signature, International Conference on Computer and Communication Technologies in Agriculture Engineering (CCTAE 2010), June 12-13, 2010, Chengdu, China, pp. 565- 567.

[4] Chenglian Liu, Jinsong Zhan. Comment on an Enhanced RSA-Based Partially Blind Signature, Applied Mechanics and Materials, Vol. 71-78, pp. 3207-3212, 2011.

[5] Chenglian Liu, Marjan Kuchaki Rafsanjani, Liyun Zheng. Comment on the Improvement of an Efficient ID-based RSA Multisignature, Second International Workshop on Trust Management in P2P Systems, Kochi, Kerala, India, July 22-24, 2011.

[6] Yongning Guo and Chenglian Liu. Comment on a Research and Analysis Four-Prime RSA, Advances in Electronic Engineering, Communication and Management, Vol. 2, Volume 140 of the series Lecture Notes in Electrical Engineering, pp. 669-675, 2012.

[7] Ping Li and Yong Li. A mixture encryption algorithm based on XOR operation, Journal of Qujing Normal University, Vol. 32, No. 3, pp. 39-42, May 2013. (Chinese version)

[8] Chenglian Liu, Yongning Guo and Juan Lin. Security analysis of RSA cryptosystem algorithm and it's properties, AIP Conference Proceeding, Vol. 1618, pp. 468-470, 2014.

[9] Chenglian Liu, Chin-Chen Chang, Zhi-Pan Wu and Shi-Lin Ye. A Study of Relationship between RSA Public Key Cryptosystem and Goldbach's Conjecture Properties, International Journal of Network Security, Vol. 17, no. 4, pp. 445-453, 2015.

[10] Jieling Wu and Chenglian Liu. A Study of Anonymous Delivery Based on Blind Signature Scheme, Procedia Computer Science, Vol. 52, pp. 1065-1070. 2015.

[11] Xiao-Tong Zhang, Chenglian Liu and Jie Fang. Study of Enterprise Internal Control Based on Dual Complexity and Anonymity Information System, Journal of Fuqing Branch of Fujian Normal University, Vol. 5, No. 138, pp. 27-34, 2016.

[12] and Donald Gardner. Weakness of RSA cryptosystem characteristic, International Conference of Computational Methods in Sciences and Engineering 2018 (ICCMSE 2018), AIP Conference Proceedings, Vol. 2040, pp. 130005-1–130005-7, 2018.

[13] Han-Bing Yan, Chenglian Liu and Lin-Shan Huang. Comment on Zhang et al.'s Anonymous Information Scheme, Journal of Fuqing Branch of Fujian Normal University, Vol. 2, No. 141, pp. 23-29, 2017.

[14] Jie Fang and Chenglian Liu. A Generalize Estimating the of Upper/Lower Bound to RSA Public Key Cryptosystem, International Journal of Network Security, Vol. 20, No. 2, pp .332-336, March 2018.

[15] Cheng Zhang, Yong-Zhang Luo and Chenglian Liu. A Dynamic Passcode System for Mobile Purchasing Without Bank Card, The 9th International Symposium on Parallel Architectures, Algorithms and Programming (PAAP' 18), December 26-28, 2018, Taipei, Taiwan.

[16] Chenglian Liu, Chien-Wen Hsu, Chunyuan Tao and Guangpu Chen. Study of anonymous based on the Letters and Visits Information System, Journal of Fuqing Branch of Fujian Normal University, Vol. 2, pp. 46-52, 2018.

[17] Jian Hong Zhang, Xue Liu, Cheng Lian Liu. A RSA-Based Data Integrity Check without Original Data in the Cloud Computing, Applied Mechanics and Materials (AMM), Vol. 44-47, pp. 3726-3730, 2011.

[18] Chenglian Liu and Chieh-Wen Hsu. Comment on "Improved Secure RSA Cryptosystem (ISRSAC) for Data Confidentiality in Cloud", International Journal of Network Security, Vol. 21, No. 4, pp. 410-413, 2019.

[19] Sonia C-I Chen and Chenglian Liu. Comment on Secure File Storage and Retrieval in Cloud, 17th International Conference of Numerical Analysis and Applied Mathematics, September 23-28, 2019, Greece.

[20] Guiyu Yang, Hongxuan Liu, Chenglian Liu and Sonia C-I Chen. Comment on MRSAC Scheme, The 9th International Conference on Industrial Technology and Management (ICITM 2020), 11-13 February, 2020, St Anne's College, University of Oxford, UK.

[21] Zhengrun Zhong, Hongxuan Liu, Sonia C-I Chen, Chenglian Liu and Donald Gardner. Comment of Secure File Storage and Retrieval in Cloud Based on MRSA Cryptographic Algorithm, The 9th International Conference on Industrial Technology and Management (ICITM 2020), 11-13 February, 2020, St Anne's College, University of Oxford, UK.

[22] R. L. Rivest, A. Shamir, and L. Adleman. A method for obtaining digital signatures and public-key cryptosystems, Communications of the ACM, Vol. 21, No. 2, pp. 120-126, Feb. 1978.

[23] Euler totient function Wikipedia website, 2019-02-02.

[24] Carmichael totient function Wikipedia website, https://en.wikipedia.org/wiki/Carmichael_function, 2019-02-02.

Detection Method of Computer Room Personnel Based on Improved Swin Transformer

Qiong-lan NA [a1], Dan SU [a], Hui-min HE [a], Yi-xi YANG [b], Shi-jun ZHANG [a], Yi-fei WANG [a] and Yu-jia MA [c]

[a]*State Grid Jibei Information and Telecommunication Company, Beijing 100053, China*
[b]*State Grid Information and Telecommunication Branch, Beijing 100761, China*
[c]*Shanxi Pengtong Construction Project Management Co., LTD, Taiyuan 030000, China*

Abstract. The accurate detection of computer room personnel can bring great convenience to computer room management and computer room inspection. Swin Transformer is used in object detection and achieves excellent detection performance. In this paper, Swin Transformer is used as the baseline to achieve accurate detection of computer room personnel. This paper mainly makes the following two contributions:1) In this paper, a practical self-attention method is designed. The channel interaction module is used in the self-attention calculation to solve the problem of local window self-attention lacking orientation awareness and location information. Reduce the size of input tokens through depth-wise convolution to reduce the complexity of self-attention calculation. 2) Use a balanced L_1 loss and configure the weights of different stages of loss in the total loss function to solve the problem of imbalance between simple samples and difficult samples. Compared with the original Swin Transformer, the improved method improves the detection accuracy of $mAP_{@0.5}$ by 3.2%.

Keywords. Swin Transformer, Personnel Detection, Self-Attention, Depth-wise Convolution

1. Introduction

At present, the managers of many computer rooms have to be on duty 24 hours a day, relying mainly on manual observation, which will consume a lot of human resources and also cause waste of video surveillance resources. For other intruders, it may pose a threat to the data transmission, storage, and system operation of the computer room. The real-time accurate detection of personnel using video surveillance in the computer room can issue early warnings to administrators promptly, and administrators can remotely record, analyze and communicate the activities of personnel entering the computer room. Therefore, realizing the accurate detection of computer room personnel can improve the

---

maintenance efficiency of the unattended computer room, and provide guarantee and convenience for the management of the computer room and the inspection of the computer room.

Recently, Swin Transformer [1] was proposed to build a hierarchical feature structure, which can easily adapt to feature pyramids, etc. And it reduces the complexity from quadratic to linear based on the self-attention computation of local windows. These features make Swin Transformer useful as a general model for various vision tasks. However, Swin Transformer still has two problems in the accurate detection of people: (1) Performing self-attention within non-overlapping windows still has high computational complexity. It will lack orientation awareness and position information, that is, it cannot capture cross-channel information well. (2) During the training process, there is also an imbalance between the simple samples and the difficult samples. When the gradient is back-propagated, the gradient effect of the simple samples is too small[2].

The improved Swin Transformer can improve these two problems: In this paper, a practical self-attention method is designed, Using the channel interaction module in the self-attention calculation can solve the problem that the local window self-attention lacks direction awareness and position information. Reduce the size of input tokens through Dw convolution to reduce the complexity of self-attention calculation. Using a balanced L_1 loss and configuring the weights of different stages of loss in the total loss function to solve the loss imbalance problem.

2. Related Work

Because the scene of personnel detection in the computer room is relatively new, at present, few researchers apply and study-related detection algorithms in this scene. Next, the development status of target detection algorithms will be described from the perspectives of convolution-based target detection algorithms and vision transformer-based target detection algorithms.

Convolution Based Object Detection. The general target detection algorithm can be divided into one-stage and two-stage methods. In the one-stage detection algorithm, Overfeat [3] directly uses convolution feature graph to predict the decision value of classification and location. YOLOV1 [4] and YOLOV3 [5] regress object boundaries and category probabilities directly based on image grids. SSD [6] improves single-stage detection with multi-layer features of various sizes. RetinaNet [7] proposed Focal loss to solve the problem of foreground-background imbalance. In the two-stage detection algorithm, R-CNN [8], Fast R-CNN [9], and Faster R-CNN [10] use the pooling features of the proposed region to predict object scores and boundaries. R-FCN [11] introduced location-sensitive fractional graphs to share each ROI feature calculation. Denet [12] predicts and searches the sparse angular distribution of object boundaries. Cascade R-CNN [13] uses sequential R-CNN stages to gradually refine the detected boxes.

Vision Transformer. Recently, the Transformer-based detector DETR [14] defines target detection as a direct ensemble prediction task and has achieved excellent results. DETR predicts a set of objects by using a converter decoder to participate in the query of the feature graph. The original architecture of DETR is simply based on Transformer [15], which contains multi-layer attention encoders and decoders. The set prediction training in DETR is based on the binary matching between the prediction and the real object. Although DETR is better than the competitive Faster R-CNN baseline, it still has some problems, such as limited spatial resolution, the poor performance of small object

detection, and slow convergence speed of training. There are already several tasks to solve these problems. Deformable DETR [16] considers the shift equivalence in natural images and introduces a series of multi-scale deformable attention operators into the encoders and decoders of DETR.

3. Proposed Method

3.1. Overall Architecture

The network structure of this paper consists of four parts, including the Swin-T backbone network, the feature pyramid (FPN), the region proposal network (RPN), and the cascaded detection head. Swin Transformer is used to extract image features, and FPN is mainly used to extract multi-scale features. RPN is a combination of several convolutional layers that produce regions of interest (ROIs) where objects may be present. The cascaded detection heads classify and localize the region of interest, and output the final detection result. In the cascade detection head, ROI Align is used for regional feature alignment, POOL represents the last part of feature extraction. FC is the fully connected layer, C is the classification probability, and B is the regression of the candidate box.
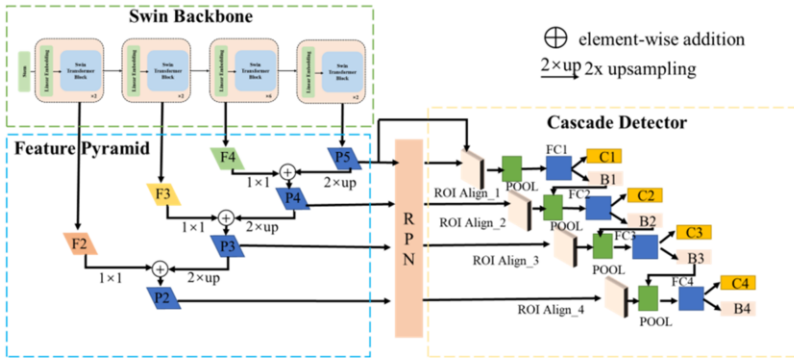
Figure 1. The overall framework of the improved algorithm

3.2. Improved Swin Transformer Backbone Network

Improved self-attention module. The improved attention module in this paper adds two key designs to the standard window-based attention module (W-MSA): (1) Design a self-attention mechanism that requires less computation to reduce the computational complexity of the self-attention mechanism spend. (2) The calculation of the V value uses the channel interaction module to solve the problem of lack of orientation awareness and position information. This paper integrates these two key points and builds an improved self-attention module. Details are described next. As shown in Figure2(c), the query $Q \in \mathbb{R}^{n \times d_k}$ is obtained by linearly projecting the input $X \in \mathbb{R}^{n \times d_m}$, where $n = H \times W$. Reshape the input $X \in \mathbb{R}^{n \times d_m}$ to a spatial vector (d_m, H, W). Reduce the size of input X by Depth-wise Convolution with kernel $s \times s$ and stride s. The size of tokens changed from (d_m, H, W) to $\left(d_m, \frac{H}{s}, \frac{W}{s}\right)$. After linear transformation to get $K \in \mathbb{R}^{n' \times d_k}$. where X is the input token, n is the number of blocks, H is the number of image blocks

in the height direction of the input image, W is the number of image blocks in the width direction of the input image, d and $_m$ is the embedding dimension of each image block, the query vector dimension, the key vector The embedding dimension of the sum-value vector is d_k, and n' is the number of blocks.

For the value of V, we add the channel interaction module to calculate. Inspired by SE, the channel interaction consists of aan DW_2, a global average pooling layer (GAP). Then there are two consecutive 1×1 convolutional layers, batch normalization (BN) and activation between them (SILU). Finally, we use sigmoid to generate attention in the channel dimension. The formula for calculating V is as follows:

$$V = FC(LN(DW_1(X))).Sigmoid(conv(SILU(BN(conv(GAP(DW_2(x))))))) \quad (1)$$

Among them, FC is fully connected, LN is layer normalization, BN is batch normalization, DW_1 is depth-wise convolution, X is input token vector, conv is 1×1 convolution, GAP is global average pooling, and DW_2 is depth-wise convolution.

where $V \in \mathbb{R}^{n' \times d_k}$, $n' = \frac{H}{s} \times \frac{W}{s}$. where DW_2 is the Depth-wise Convolution with a convolution kernel of 3×3, and the difference between DW_1 and DW_2 needs to be noted here. The input size of DW_1 is reduced by a factor of s, DW_2 does not change the size and number of channels of the input, More channel information is preserved. Then, the self-attention functions of Q, K, and V are calculated by the following formula 2:

$$MSA(Q,K,V) = LN\left(Softmax\left(\frac{QK^T}{\sqrt{d_k}}\right)\right)V \quad (2)$$
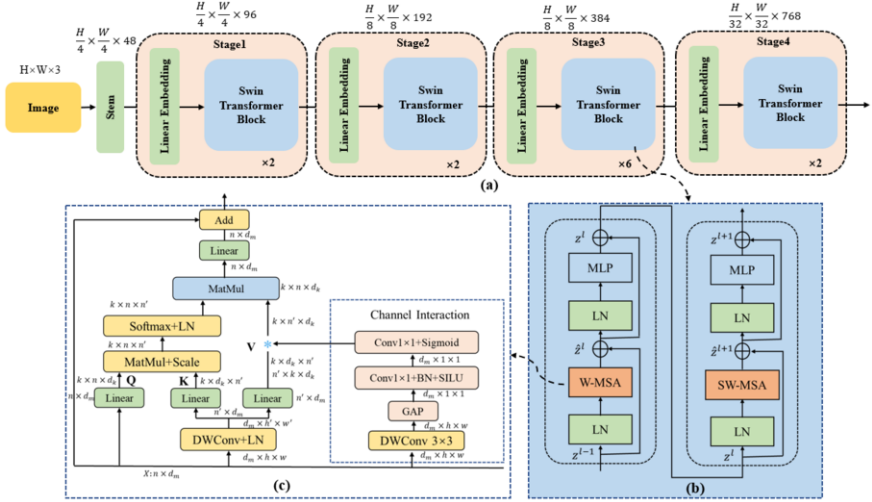
Figure 2. Improved Swin-T backbone network

3.3. Improved Loss Function

RPN classification loss and cascade detection head loss. This paper uses the multivariate cross-entropy loss function, and the goal of bounding box classification assigns C+1 class labels to each bounding box, denoted by probability p. Among them, C is all the categories, and 1 is the background. For the training samples x_i and y_i, where

y_i is the true label value of the input x_i, the multivariate cross-entropy loss function is as formula 3:

$$CE(p, y) = -\frac{1}{C+1}\sum_{j=0}^{C+1} W_j log(p_i)$$

(3)

Among them, W_j is as formula 4:

$$W_j = \begin{cases} 1, |x| < 1 \\ 0, otherwise \end{cases}$$

(4)

RPN bounding box regression loss. Bounding box regression aims to regress the candidate bounding box $b = (b_x, b_y, b_w, b_h)$ to the target bounding box $g = (g_x, g_y, g_w, g_h)$ using the regression function, minimizing the loss function $L_{BIoc}(b_i, g_i)$ as formula 5:

$$L_{BIoc}(b_i, g_i) = \frac{1}{N_{reg}}\sum_i P_i^* L_{Ioc}(b_i, g_i)$$

(5)

Among them,

$$L_{Ioc}(b_i, g_i) = \sum_i Smooth_{L_1}(b_i - g_i)$$

(6)

$$smooth_{L_1} = \begin{cases} 0.5x^2, |x| < 1 \\ |x| - 0.5, otherwise \end{cases}$$

(7)

Among them, N_{reg} represents the number of anchor positions, P_i^* is 1 when the candidate frame is a positive sample, P_i^* is 0 when the candidate frame is a negative sample, b_i represents the bounding box regression parameter for predicting the i-th anchor , g_i represents the ground-truth box corresponding to the i-th anchor.

Cascaded detection head bounding box regression loss. When the weight of the regression loss increases, the model is very sensitive to abnormal values of the regression coordinates. In this paper, $L1_{balanced}$ is used as follows:

$$L1_{balanced}(\hat{x}) = \begin{cases} \frac{\alpha}{b}(b|\hat{x}| + 1)ln(b|\hat{x}| + 1), |\hat{x}| < 1 \\ \gamma|\hat{x}| + C, otherwise \end{cases}$$

(8)

Among them,

$$\alpha ln(b + 1) = \gamma$$

(9)

Among them, α is the weight coefficient of outliers, γ is used to limit the range of outliers, α and γ are hyperparameters, and the default values are set to 0.5 and 1.5. The parameter b can ensure that the derivative is continuous, and C is a constant. The relationship between hyperparameters is shown in Equation 9.

Total loss. The total loss is defined as follows:

$$L = aL_{RPN} + bL_{stage1} + cL_{stage2} + dL_{stage3}$$

(10)

Among them,

$$L_{RPN} = L_{RPN\_cls} + L_{RPN\_reg}$$

(11)

$$L_{stage1} = L_{stage1\_cls} + L_{stage1\_reg}$$

(12)

$$L_{stage2} = L_{stage2\_cls} + L_{stage2\_reg} \qquad (13)$$

$$L_{stage3} = L_{stage3\_cls} + L_{stage3\_reg} \qquad (14)$$

a, b, c and d represent the weight coefficients of the loss. For the computer room personnel detection task, the weight coefficients a, b, c, and d are set to [1, 0.75, 0.5, 0.25], respectively. L_{RPN_cls} represents the RPN classification loss, and L_{RPN_reg} is the RPN regression loss. L_{stage1}, L_{stage2} and L_{stage3} represent the total loss of the three stages, L_{stage1_cls}, L_{stage2_cls} and L_{stage3_cls} are the classification losses of each stage, L_{stage1_reg}, L_{stage2_reg} and L_{stage3_reg} are the regression losses for each stage. L_{stage1_reg}, L_{stage2_reg} and L_{stage3_reg} apply a balanced L1 loss function.

4. Results and Discussion

4.1. Experiment setup

Constructing a dataset: We extract surveillance videos from multiple computer rooms, cut frames manually, and filter according to lighting conditions, picture integrity, etc. Annotate according to the normalization method to construct a person detection dataset. The dataset contains 5137 images and 14398 labels, and the label's category is person. Most of the image sizes in the dataset are 1980*1080, and a few are 720P.

Experimental setup: The IOU threshold for cascaded detection heads is [0.5, 0.6, 0.7]. The batch size is set to 64, the learning rate is kept at 0.01 during the 1st to 7th epochs, and dropped by a factor of 0.1 after the 8th to 12th epochs. ADAMW optimizer, Data augmentation includes random horizontal flipping, random scaling, and random cropping. In the Swin Transformer module, the Patch Size is set to 2×2, the head is set to 8, and the embedding is set to 64, The experimental equipment in this paper uses two GTX 3090s, and the improved algorithm is implemented based on MMdetection.

4.2. Experimental results

To verify the performance of the improved detection network, this paper will compare with the current popular target detection algorithms, test DETR based on ResNet50, Deformable DETR based on ResNet50, YOLOX-x, Retinanet based on ResNext101, and using FPN, YOLOF algorithm based on ResNet50 and The detection performance of the cascaded Swin Transformer-T and other algorithms is shown in Table 1. First, considering the mAP value of *IoU=0.5,* the detection accuracy of Swin Transformer is better than that of DETR, Deformable DETR, and YOLOF, and the detection accuracy of Swin Transformer is 0.05 points higher than that of the one-stage algorithm Retinanet. This seems to indicate that the two-stage algorithm has higher detection accuracy than the end-to-end and one-stage algorithms in the field of computer room personnel detection. Of course, this does not include YOLOX-x, because YOLOX is mainly a collection of various techniques. The detection accuracy of YOLOX-x is better than that of Swin Transformer. Deformable DETR is 1.4 points higher than DETR in detection accuracy. The detection network in this paper is based on the improved Swin

Transformer detection network $mAP_{@0.5}$ is 89.8%, which is 3.2 points higher than the detection accuracy of Swin-T. The detection accuracy of the improved algorithm in this paper is 0.6 points higher than that of YOLOX-x. Secondly, in terms of detecting small objects, the improved algorithm in this paper is second only to YOLOX in detecting small objects, and the DETR series algorithms have the worst performance in detecting small objects. Deformable DETR has a higher detection performance than DETR for small objects. In addition to YOLOX, the two-stage detection algorithm is significantly better than the one-stage algorithm in detecting small objects. Finally, in terms of model complexity, to ensure fairness, the input size of all target detection networks is set to (3, 1280, 800). Compared with Swin Transformer, the GFLOPS in this paper is reduced by 5.43G and the number of parameters is increased by 3.42M. The improved method in this paper has a huge improvement in the detection accuracy of the Swin Transformer.

Table 1. Results of different detection methods

Method	AP	AP_{50}	AP_{75}	AP_S	AP_M	AP_L	GFLOPs	Par
DETR[14]	0.469	0.794	0.408	0.238	0.438	0.574	91.64	41.3
De_DETR[16]	0.486	0.808	0.426	0.288	0.445	0.559	195.26	39.84
Retinanet[17]	0.502	0.816	0.452	0.319	0.488	0.593	315.39	56.74
YOLOX-x[18]	0.608	0.893	0.652	0.384	0.525	0.702	352.42	99.07
YOLOF[19]	0.504	0.818	0.443	0.287	0.452	0.583	99.98	43.88
Swinr[1]	0.588	0.866	0.627	0.378	0.521	0.715	263.78	47.79
Improved Swin	0.614	**0.898**	0.645	0.381	0.505	0.722	258.35	51.21

4.3. Ablation experiment

We use Swin-T as the baseline algorithm, and then test each improved detection performance on this basis, and measure the detection performance by $mAP_{@0.5}$. The experimental results are shown in Table 2, and the detection accuracy is improved by 1.83 points using the improved Swin Transformer module (ISTB). Using a balanced loss function (BLOSS), the detection accuracy improves by 1.4 points. Therefore, the comprehensive use of the improved method in this paper can improve the detection accuracy of Swin Transformer.

Table 2. Results of different detection methods

Method	$mAP_{@0.5}$
Swin-T	0.866
+ISTB	0.884
+ISTB+BLOSS	0.898

4.4. Visualization
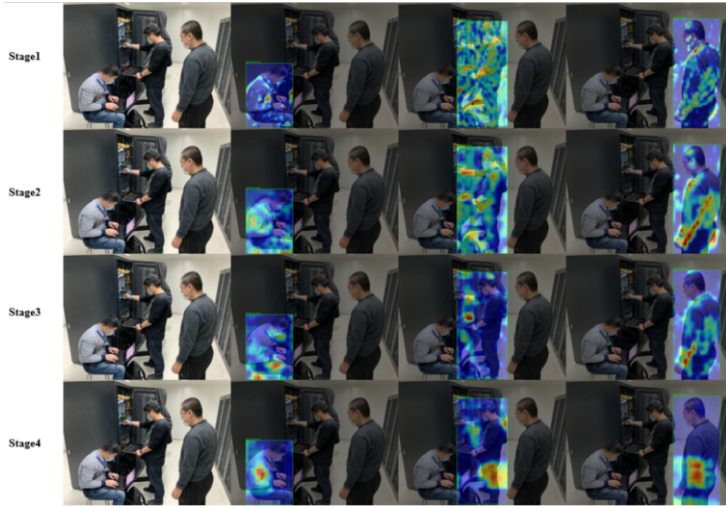
Figure 3. Multi-self-attention visualization of different stages of Swin-T

Visualize the multi-self-attention of different stages of Swin-T to illustrate how the channel interaction module collects global information. As shown in Figure 3, the first and second columns represent the Stage and the original image of the backbone network; while the other columns represent the heatmap visualization of the last multi-head self-attention feature of the same target in different Stages, The visualization shows that the channel interaction module seems to be able to select globally important regions and suppress background regions for better detection.

5. Results and Discussion

In this paper, Swin Transformer is used for the first time in computer room personnel detection. In this paper, a practical self-attention method is designed. The use of channel interaction module in self-attention calculation can solve the problem of limited self-attention receptive field of local windows. Depth-wise Convolution is used to reduce the size of the input tokens to reduce the self-attention calculation complexity. In addition, a balanced L_1 loss is adopted and the weights of different stage losses are configured in the total loss function to solve the gradient imbalance problem. Experiments show that The improved method can realize the accurate detection of the personnel in the computer room, improve the maintenance efficiency of the unattended computer room, and provide guarantee and convenience for the management of the computer room and the inspection of the computer room. Our research on detecting small targets is not enough, and improving the detection accuracy of small targets will be our next research direction.

References

[1] Liu Z, Lin Y, Cao Y, et al. Swin transformer: Hierarchical vision transformer using shifted windows[C]//Proceedings of the IEEE/CVF International Conference on Computer Vision. 2021: 10012-10022.

[2] Pang J, Chen K, Shi J, et al. Libra r-cnn: Towards balanced learning for object detection[C]//Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2019: 821-830.

[3] Sermanet P, Eigen D, Zhang X, et al. Overfeat: Integrated recognition, localization and detection using convolutional networks[J]. arXiv preprint arXiv:1312.6229, 2013.

[4] Redmon J, Divvala S, Girshick R, et al. You only look once: Unified, real-time object detection[C]//Proceedings of the IEEE conference on computer vision and pattern recognition. 2016: 779-788.

[5] Redmon J, Farhadi A. Yolov3: An incremental improvement[J]. arXiv preprint arXiv:1804.02767, 2018.

[6] Liu W, Anguelov D, Erhan D, et al. Ssd: Single shot multibox detector[C]//European conference on computer vision. Springer, Cham, 2016: 21-37.

[7] Lin T Y, Goyal P, Girshick R, et al. Focal loss for dense object detection[C]//Proceedings of the IEEE international conference on computer vision. 2017: 2980-2988.

[8] Girshick R, Donahue J, Darrell T, et al. Rich feature hierarchies for accurate object detection and semantic segmentation[C]//Proceedings of the IEEE conference on computer vision and pattern recognition. 2014: 580-587.

[9] Girshick R. Fast r-cnn[C]//Proceedings of the IEEE international conference on computer vision. 2015: 1440-1448.

[10] Ren S, He K, Girshick R, et al. Faster r-cnn: Towards real-time object detection with region proposal networks[J]. Advances in neural information processing systems, 2015, 28.

[11] Dai J, Li Y, He K, et al. R-fcn: Object detection via region-based fully convolutional networks[J]. Advances in neural information processing systems, 2016, 29.

[12] Tychsen-Smith L, Petersson L. Denet: Scalable real-time object detection with directed sparse sampling[C]//Proceedings of the IEEE international conference on computer vision. 2017: 428-436.

[13] Cai Z, Vasconcelos N. Cascade r-cnn: Delving into high quality object detection[C]//Proceedings of the IEEE conference on computer vision and pattern recognition. 2018: 6154-6162.

[14] Carion N, Massa F, Synnaeve G, et al. End-to-end object detection with transformers[C]//European conference on computer vision. Springer, Cham, 2020: 213-229.

[15] Vaswani A, Shazeer N, Parmar N, et al. Attention is all you need[J]. Advances in neural information processing systems, 2017, 30.

[16] Zhu X, Su W, Lu L, et al. Deformable detr: Deformable transformers for end-to-end object detection[J]. arXiv preprint arXiv:2010.04159, 2020.

[17] Lin T Y, Goyal P, Girshick R, et al. Focal loss for dense object detection[C]//Proceedings of the IEEE international conference on computer vision. 2017: 2980-2988.

[18] Ge Z, Liu S, Wang F, et al. Yolox: Exceeding yolo series in 2021[J]. arXiv preprint arXiv:2107.08430, 2021.

[19] Chen Q, Wang Y, Yang T, et al. You only look one-level feature[C]//Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2021: 13039-13048.

The Exploration of the Teaching Reform in the Course of "Drawings Recognition in Construction Engineering" for the Veterans Under the Background of "1+X" Certificate System: Take a Private University in Hainan Province as an Example

Faxin HU[a] and Yuanyuan CHEN [b,1]

[a]*Hainan United Zhenhua Real Estate Appraisal and Consulting Co., Ltd., Haikou, China*
[b]*School of Intelligent Automobile and Engineering, Sanya Institute of Technology, Hainan, China*

Abstract. A private college in Hainan Province is exemplified to introduce the construction logic of the school's civil engineering group who is offered basic courses of "Architectural Drawing Recognition and Construction" and "Engineering Drawing". The veterans are faced with the dual pressure of both work and study, and how to get the veterans to pass the "1+X"construction engineering drawing examination is a difficult problem for the majority of educators. Due to the limited offline teaching hours, the veterans must actively promote the integration of course and certificate. The list introduces the comparison of the course setting and teaching content before and after the "1+X" course and certificate integration, which reflects the professional skill level standards for construction engineering drawings after the course certificate integration. At the same time, it constructively explore the practice of integrating Revit and BIM civil engineering measurement GTJ2021 software into the course of "Architectural Drawing and Construction". Finally, the dilemma and breakthroughs of implementing the "1+X"certificate of construction engineering drawing recognition are proposed from the level of students, teachers and enterprises.

Keywords. "1+X" certificate, professional group, drawing recognition of construction engineering, engineering drawing, course and certificate integration

---

¹ Corresponding Author, Yuanyuan CHEN, School of Intelligent Automobile and Engineering, Sanya Institute of Technology, Hainan, China; Email: 983877012@qq.com

1.Introduction

The National Vocational Education Reform Implementation Plan was promulgated at the beginning of 2019. The case clearly stated that the pilot work of the "1+X" certificate system should be widely initiated and carried out in vocational colleges. The civil engineering major offers basic professional courses of "Architectural Drawing and Structure" and "Engineering Drawing". How to integrate professional basic courses with the "1+X"course certificate, and how to face the difficulties and breakthroughs in implementing the "1+X"construction engineering drawing certificate from students' level, teachers' level, and enterprises' level are the problems that the civil engineering professional group needs to solve .

Premier Li Keqiang stated in his government work report on March 5, 2019: "This year, higher vocational colleges will enrol 1 million people on a large scale." The main thing is to reform and improve the enrolment methods of higher vocational colleges, and encourage more recent high school graduates, veterans, laid-off workers, and migrant workers to apply for the exam [1]. Veterans are facing the dual pressure of work and study. Some of them perform the work which is related to the major that they apply for, while some are not related to the major that they apply for. Drawing is the language of engineering. It is the basic knowledge that veterans who apply for the civil engineering professional group must master. How to enable veterans to better learn the professional basic courses of "Architectural Drawing and Construction" and "Engineering Drawing", and strive to pass ""1+X" "Construction engineering drawing examination is a difficult problem faced by the majority of educators. The professional basic courses of "Architectural Drawing and Construction" and "Engineering Drawing" are the basic courses that veterans who apply for the civil engineering group must master. For the reason that veterans have limited offline teaching hours, it is therefore necessary to actively promote the integration of course and certificate. Moreover, teaching veterans to master architectural projection rules, architectural drawing standards, and the use of CAD drawing software during the limited offline teaching hours that veterans have. A set of small-scale construction engineering drawings acts as the carrier to complete the task of recognizing and drawing architectural professional drawings, and develop basic professional qualities through the knowledge and understanding of national technical standards and standards.

2.Literature Review

Kong Yuqin [2] , Emperor Yao [3] proposed A 3D model of small and medium-sized engineering drawings suitable for teaching is established by using BIM technology, which is applied to the understanding of architectural structure and the teaching of engineering drawings. The traditional teaching mode is reformed, gradually changing from the previous abstract and boring learning mode to the vivid three-dimensional learning mode with the help of computer, so as to meet the social needs of the major. BIM technology is introduced, and the information technology is organically integrated with traditional course teaching.

Zhao Yingying[4] proposed the traditional teaching method has been difficult to achieve the teaching goal of abstract architectural professional courses, and MR technology has brought new possibilities to education with its powerful advantages. Li Ke, He Lizhi, Zheng Qiaoling[5], Xu Lili[6] proposed to restructure course content

modules, introduce actual enterprise engineering projects, carry out project-based learning based on information technology, and jointly build online resources for courses by schools and enterprises, and explore "1+X" Curriculum construction model led by learning maps and a mixture of internal and external teaching. Tan Xiaoyan, Zhang Hongyao[7] proposed deepening the combination of "1+X"vocational skill certificate and curriculum construction in the reform of "teachers, textbooks and teaching methods" and puts forward some reasonable suggestions for this reform of relevant professional courses. Wang Jian [8] proposed to realize the intelligent learning of construction drawing recognition skills by combining IT technology and adopting modern scientific and technological means.

3. Construction logic of civil engineering professional group

In consideration of the life cycle of the real estate industry, majors in real estate operation and management, architectural design, architectural engineering technology, architectural decoration engineering technology, construction engineering supervision, engineering cost and property management have been set up focusing on the early stage of the project, bidding phases, construction phases, decoration phases, and operation phases in accordance with the professional group construction idea of "connecting the real estate industry chain, optimizing the real estate professional chain, building the real estate professional group, innovating the service chain, and activating the talent training chain based on the job chain". Real estate operation and management, and project construction cost will provide talent services for the real estate industry at different stages of the real estate industry's life cycle throughout the entire industrial chain. Project construction cost provides services such as investment budget, design budget, construction drawing budget, base price, quotation, contract price, construction budget, settlement, and final accounts for the real estate industry chain. As shown in Figure 1. The solid ellipse indicates the major currently registered for the veterans, and the dotted ellipse indicates the major currently not registered or suspended. Among them, real estate operation and management, previously called Real Estate Operation and Valuation started in 2009 and its enrolment was stopped in 2014. The main reason for the suspension of enrolment was the decline in enrolment due to the constraints of the development of the real estate industry in Hainan Province. Construction project supervision started recruiting students in 2012 and stopped recruiting in 2017. The main reason was with the development of Hainan's economy, vocational students and parents are more inclined to choose majors with technical content, available job vacancies and good development prospects. Construction engineering majors are more inclined to choose construction costs, construction engineering technology, resulting in the declining enrolment in construction project supervision. In 2017, the major of architectural decoration engineering began to recruit students to the scale of about one class a year. Architectural design and property management were not opened. After an early-stage market research and demonstration, property management enrolment was relatively small across the country, though property management companies can provide a large number of job vacancies. However, the low employment thresholds and low salary income led to poor students' willingness to apply for the exam. Architectural design majors are difficult to learn and require relatively high professional standards for students. Students who apply for majors in private colleges are subject to multiple considerations of their own learning status and employment, and their willingness to

apply for it is not high. Hence there is only one higher vocational college in Hainan Province that opens this major with a stable enrolment scale of about one class.

Drawings are the language of engineering, and drawing recognition and drawing are necessary skills for engineering majors. The three majors of engineering cost, construction engineering tec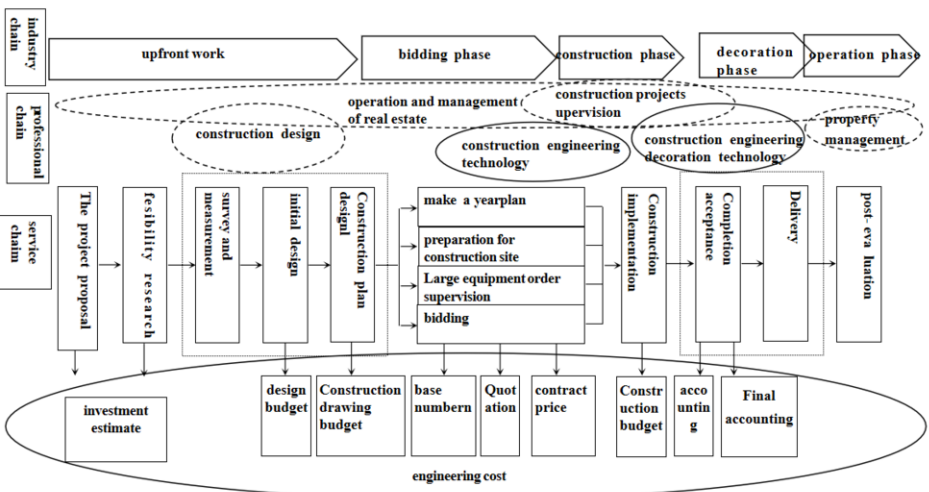hnology, and architectural decoration engineering technology all offer basic professional courses of "Architectural Drawings and Structures" and "Engineering Drawings". Since 2009, around 300 veterans have applied for three majors in engineering cost, construction engineering technology, and architectural decoration engineering technology.

Figure 1 Schematic diagram of the correspondence between civil engineering professional groups and industries

4. Comparison of curriculum setting and teaching content before and after "1+X"course and certificate integration

Considering that the students are senior veterans who have weak abstract thinking, it is not appropriate to choose abstract declarative knowledge for the course content [9]. The course "Architectural Recognition and Structure" before the integration of course and certificate weakens the explanation of projection knowledge given the fact that their sense of three-dimensional space is not strong. It mainly teaches students to read design instructions, general layout, plan, standard floor plan, elevation, detailed drawing, stair plan, stair section, detailed drawings of stair nodes and independent foundations, strip foundations, raft foundations, pile cap foundations, pile foundations, stair reinforcement plane method, column reinforcement plane method, shear wall reinforcement plane method, beam reinforcement plane method, slab reinforcement plane method and other structural diagrams.

In accordance with the "1+X"vocational skill level standard for building engineering drawing recognition, the "Architectural Drawing Recognition and Structure" course after the integration of course and certificate strengthens the basic principles of projection, and adds the learning and reading of drawing specifications and axonometric drawings. By increasing the class hours of this part, the passing rate

of the elementary level and intermediate level of students has been increased and the foundation of drawing recognition has been laid.

Only the course of "Engineering Drawing (AUTOCAD)" was offered before the course and certificate were integrated. After a survey the veterans believe that the CAD software which is offered for only one semester, is forgotten later during the internship. It is recommended to set up a two-semester drawing course to consolidate the learning content. Considering the actual situation of the school's computer room, the course "Engineering Drawing (Zhongwang CAD)" was added after the course certificate was integrated. Two-semester teaching is convenient for veterans to better master the drawing software. At the same time, students are required to draw three-sided projections of points, lines, surfaces, and bodies, to draw the isometric and oblique two-dimensional drawings of the body, and to draw the construction drawings and detailed structural drawings of the construction engineering foundation, column (wall), beam, and slab. These have enriched the teaching content and improved the skill level of the students.

Vocational colleges and social institutions must take into account the essential feature between vocational education and vocational training when launching the "1+X" certificate system pilot program and avoid shortening the class and class hours or compressing the knowledge and skills that should be imparted in order to obtain the vocational skill level certificate. Otherwise vocational education becomes vocational training [10]. Table 1 shows the comparison of curriculum settings and teaching content before and after the course certificate integration.

5. Exploration of integrating Revit and BIM civil engineering measurement GTJ2021 software into the course of "Architectural Drawing and Construction"

The course of "Architectural Drawing and Recognition" is to cultivate students' imagination and shape conception ability from space to plane, and then from plane to space. For complex shapes, as well as the drawing of sections and cross-section, students are required to have strong space imagination which makes it difficult for them to understand [11]. Revit can facilitate teachers and students to compare the projection views in different directions of the model, which can effectively help students understand and master the projection law; it can facilitate teachers and students to observe the difference of projection graphics of different featured models, and help students to establish the mapping between projection graphics and three-dimensional models, thus improving students' ability to read drawings [12].

Through drawing by BIM civil engineering measurement GTJ2021 software, one can convert two-dimensional drawings into three-dimensional drawings. Students can combine learning with strong intuitiveness and achieve better teaching effects. At the same time, students can view the engineering quantity of the steel bar after the calculation, check the reinforcement situation and anchoring situation of the steel bar, learn more intuitively and understand more thoroughly. The combination of the abstract plane drawing with the three-dimensional drawing makes it more visual and effective to solve the problem of poor spatial imagination of students and contribute to the study of veterans in higher vocational colleges.

Table 1 the comparison of curriculum settings and teaching content before and after the course certificate integration

The comparison of the course setting and teaching content before and after the "1+X" course and certificate integration				
	Before course and certificate integration		After course and certificate integration		
Course setting	Architectural Drawing and Construction	Engineering Drawing	Architectural Drawing and Construction	Engineering Drawing (AutoCAD)	Engineering Drawing(Zhongwang CAD)
class	64	64	64	32	64
Semester	First Semester of the freshmen year	First Semester of the freshmen year	First Semester of the freshmen year	First Semester of the freshmen year	Second Semester of the freshmen year
Key points	Know about basic principles of projection		Master basic principles of projection	Master drawing specifications	
			Know drawing specifications well	Master the drawing methods and formation principles of axonometric drawings	
			Master the basic knowledge of axonometric drawings	Master the drawing methods and formation principles of cross-section	
	Know about the notes and types of section and cross-section	Master the drawing methods and formation principles of construction plan	Know about the notes and types of section and cross-section	Master the drawing methods and formation principles of construction plan	
	Know about the basic knowledge of construction drawings and relative regulations	Master the drawing methods and formation principles of elevation	Know about the basic knowledge of construction drawings and relative regulations	Master the drawing methods and formation principles of elevation	
	Master the basic knowledge of structural construction drawings and relative regulations and now about the basic knowledge of reinforced concrete	Master the drawing methods and formation principles of section	Master the basic knowledge of structural construction drawings and relative regulations and now about the basic knowledge of reinforced concrete	Master the drawing methods and formation principles of section	
Points of skills			Recognize projections of axonometric, isometric and oblique	Draw the isometric and oblique two-dimensional drawings of the body	
	Recognize and distinguish section and cross-section	Copy the construction plan according to the given	Recognize and distinguish section and cross-section	Copy the construction plan according to the given drawings	
	Recongnize the design instructions, general layout, plan, standard floor plan, elevation, detailed drawing, stair plan, stair section, detailed drawings of stair nodes	Copy the construction plan according to the given drawings	Recongnize the design instructions, general layout, plan, standard floor plan, elevation, detailed drawing, stair plan, stair section, detailed drawings of stair	Copy the construction plan according to the given drawings	
	Recognize the independent foundations, strip foundations, raft foundations, pile cap foundations, pile foundations, stair reinforcement plane method, column reinforcement plane method, shear wall reinforcement plane method, beam reinforcement plane method, slab reinforcement plane method	Draw a section as required	Recognize the independent foundations, strip foundations, raft foundations, pile cap foundations, pile foundations, stair reinforcement plane method, column reinforcement plane method, shear wall reinforcement plane method, beam reinforcement plane method, slab reinforcement plane method	Draw a section as required	
	Proficiency in the analysis of civil building structures: foundations and basements, walls, floors, doors and windows, stairs, roofs, deformation joints, industrial buildings	Draw a cross-section as required	Proficiency in the analysis of civil building structures: foundations and basements, walls, floors, doors and windows, stairs, roofs, deformation joints, industrial buildings	Draw a cross-section as required	
					Draw basic construction drawings of construction projects; Draw column (wall) construction drawings of construction projects; Draw beam construction drawings of construction projects; Draw slab construction drawings of construction projects; Draw detailed structural drawings of construction projects

6. Difficulties and breakthroughs in implementing the "1+X"construction engineering drawing recognition certificate

So far the "1+X"construction engineering drawing recognition certificate is in its infancy and there are some problems such as low student participation, lack of enthusiasm, high pressure on teacher training, and low corporate recognition.

The school has mobilized students to sign up for the training on many occasions, but the willingness of students to sign up is not high. The main reasons are as follows: First, the training time is mostly evenings and weekends, and students are struggling to cope. Due to different classes having different class hours, students are encouraged to sign up on their own, and because training is only at night and the weekends; students feel it is tiring and are not willing to participate. The logic of subject courses can easily lead to the lack of motivation, low interest, and low learning performance of vocational education learners [13]; second, the content of the primary examination is out of touch with work practice and students are not motivated. For higher vocational students, we tend to allow students to understand construction drawings and structural construction drawings. The emphasis is on understanding the drawings. The three-sided projection method is tested in the drawing part, which is relatively abstract and inconsistent with the students' focus. It is of great difficulty in learning; third, it has a low recognition of enterprises compared with the Seven Workers certificates, thus the willingness of students to participate in the examination is low. Students also hope to obtain graduation certificates and partial post of the Seven Worker's Certificates. For the "1+X"construction engineering drawing recognition certificate, the company's recognition is currently low in the promotion stage. Students are more willing to review the contents of the Seven Workers Certificates in their spare time rather than participate in the "1+X"construction engineering drawing training. Fourth, the examination time is relatively rigid, and it is impossible to substitute certificates for examinations. As the "1+X"construction engineering drawing is in the national unified examination, there are about 4-5 examinations per year. The student has not finished the class and cannot take the exam. Arranged at the end of the semester, the students' school exams are over, and then they will take the "1+X"architectural engineering drawing test. It is impossible to substitute the certificate for the exam and improve the enthusiasm of the students. It is recommended that the primary drawing part of the "1+X"construction engineering drawing examination is still based on simple construction drawings, distinguishing architectural design, structural construction, building plumbing, and building electrical. It is recommended that the test time is to be flexible, so that the certificate can be used to replace the test and improve the enthusiasm of students. It is recommended to increase publicity, and increase enterprises' awareness of "1+X"construction engineering drawing recognition, and increase the industry's recognition of "1+X"construction engineering drawing recognition certificate, and strive to be comparable to the Seven Worker's Certificates.

Due to the heavy burden of class hours, teachers will take up a lot of time for evening and weekend training. In addition, the teacher training organized by Zhongwangongteng Software Co., Ltd. is offline, which usually takes 4-5 days. The teachers in private colleges are relatively tight, and it is difficult to have enough training time. The focus of teacher's training is to understand the pictures, which weakens the explanation of the projection, resulting in mediocre training effects. It is recommended that teacher training should be changed into online training. Only when

the teacher understands the points for the test, will they be able to review and guide students in a targeted manner.

7. Conclusion

Taking a private college in Hainan Province as an example, this article first introduces the construction logic of the school's civil engineering professional group. The civil engineering professional group provides basic courses of "Architectural Drawing and Construction" and "Engineering Drawing". Then the list introduces the comparison of the course setting and teaching content before and after the "1+X"course certificate integration, which reflects the professional skill level standard for building engineering drawing recognition after the course certificate integration. At the same time, this article constructively explores the practice of integrating Revit and BIM civil engineering measurement GTJ2021 software into the course of "Architectural Drawing and Construction". Finally, from the level of students, teachers, and enterprises, the dilemma and breakthroughs of implementing the "1+X" construction engineering drawing recognition certificate are proposed.

Only certificates recognized by the industry will have lasting vitality, and will truly be highly valued by teachers and students. In the later stage of the research, it is recommended to send some questionnaires to enterprises and industry organizations to introduce the "1+X" construction engineering drawing recognition certificate. In addition, to solicit opinions from enterprises and industry organizations on how to make the "1+X" construction engineering drawing recognition certificate more popular, and how to encourage more corporate practitioners to apply for the exam.

References

[1] Chen Rongfang, Lu Qingliang, Pan Zhibin, Lin Jinwen. Thoughts on the training of vocational education talents for the health management major of veterans〔J〕. Education Observation, 2019, 8 (28): 129-130.

[2] Kong Yuqin. The application of BIM technology in the teaching of building structure and engineering drawing[J]. China Building Materials Science and Technology, 2021, 30(01): 133-136.

[3] Yao Guohuang. Exploration of the teaching mode of civil engineering and graphics courses based on BIM technology for the expansion of higher vocational students[J]. Journal of Shenzhen Institute of Information Technology, 2021, 19(03): 78-82.

[4] Research on the application of MR technology in the teaching of architectural professional courses-taking the recognizing diagram of construction engineering steel bar as an example [J]. China Educational Technology and Equipment, 2020(18): 37-40.

[5] Li Ke, He Lizhi, Zheng Qiaoling. A preliminary exploration of the curriculum construction model of "1+ map-based learning, mixed teaching inside and outside"——Taking the course of building structure foundation and flat method map as an example[J]. University, 2021(35): 46-48.

[6] Xu Lili. Research on the implementation of a hybrid teaching strategy in connection with the "1+X"certificate system——Taking "Construction Drawings to Recognize Drawings from the Plan" as an example [J]. Guangxi Education, 2021(19): 77-79.

[7] Tan Xiaoyan, Zhang Hongyao. Exploration of the three education reforms based on "1+X"construction engineering map recognition[J]. Jiangsu Science and Technology Information, 2020, 37(36): 55-57.

[8] Wang Jian. Reform of the "1+X"certificate course for architectural structure and drawing recognition [J]. Modern Vocational Education, 2021(41): 38-39.

[9] Min Jianjie. The New Path of Vocational Education Curriculum Development——Interpretation of Jiang Dayuan's new book "New Theory on Vocational Education Research"[J]. Journal of Hubei Vocational and Technical College, 2007(02): 3-6.

[10] Yan Zhiyong, Jiang Dayuan, Wu Quanquan. The governance implications and misunderstanding avoidance of the "1+X" certificate system[J]. Education and Occupation, 2019(15): 5-12.

[11] Fang E, Song Guofang. Research on the teaching reform of "Architectural Drawing and Recognition" under the "1+X"certificate system[J]. Economist, 2020(11): 188-189.

[12] Sun Yigang.The Exploration of the teaching reform on the integration of course and certificate in the course of Drawings Recognition in Construction Engineering for the veterans major in civil engineering in higher vocational colleges under the background of "1+X" certificate system [J].Theoretical Research and Practice of Innovation and Entrepreneurship,2021,4(02):7-8.

[13] Yan Zhiyong, Jiang Dayuan, Wu Quanquan. The contemporary meaning and construction ideas of the vocational education action logic course[J]. Vocational Education Development Research, 2019(01): 24-31.

Improvement in Organizational Effectiveness Under the Background of Reform of State-Owned Enterprises: A Pilot Work of Assessment of Institutional Effectiveness of the State Grid Corporation of China

Peng CHEN, Wenhao YAN, Ai'sheng LIU, Xin MA, Tiantian ZHENG and

Yanting TAN[1]

Customer Service Center of the State Grid Corporation of China, Tianjing City,

China

Abstract. As a research hotspot in recent years, the improvement in institutional efficiency provides a new reference for the reform of state-owned enterprises and the development of new enterprises in China. The purpose of this study was to explore the value and significance of institutional efficiency in the practice of state-owned enterprises. On the basis of relevant research at home and abroad, this study took the State Grid Corporation of China "institutional efficiency evaluation pilot work" as the key case. By constructing the institutional efficiency model, it was found that a more reasonable application of the model could bring more benefits to enterprises. At the same time, under the same enterprise, different business models used different performance models. The findings of this study might bring value to the development of modern enterprise organizations and hence benefit subsequent research.

Keywords. Institutional effectiveness, management, reform of state-owned enterprises

1. Definition of Institutional Effectiveness

Institutional effectiveness, also known as organizational effectiveness, is an abstract concept in management. As a reflection of the overall efficiency and effectiveness of an

---

[1] Corresponding Author: Yanting TAN, Customer Service Center of the State Grid Corporation of China; Email: 13821068810@139.com

organization, institutional effectiveness is often used as a standard to measure the success of the organization.

Studying institutional efficiency is highly important. Only by better using scientific methods can we improve corporate institutional efficiency, which is specifically the average performance value or revenue value created by every employee, including the management team, every day. For state-owned enterprises in transition, higher organizational efficiency can bring a higher value. At the same time, finding an appropriate performance model is of great significance because many business lines exist and the management structure is relatively complex.

The connotation of organizational effectiveness has been thoroughly explored from various perspectives, resulting in a consensus on organizational effectiveness. Peter Drucker has claimed that institutional effectiveness refers to the capability of achieving goals by exploiting available resources. Institutional effectiveness is a combination of the capability of an organization to achieve goals and the results achieved on the basis of the capability [1]. Generally speaking, high-performing enterprises are those with excellent leaders and employees, advanced technology, and corporate culture in line with the company's development prospects [2]. Four leading factors, including hero leader, Chinese concept, Western standard, and channel drive and community of interests, and four output results, including enterprise culture, core competitiveness, rapid response, and vision mission, should be considered for high-performance enterprises in China.[3] Efficiency is a "continuity" problem, and the assessment of the efficiency and performance of high-performance enterprises should reflect the overall picture of enterprise management. Therefore, institutional effectiveness can be analyzed from four dimensions, including statics, dynamics, psychology, and ecology. From the perspective of organizational statics, institutional effectiveness is the extent to which an organization achieves its predetermined goals. From the standpoint of organizational dynamics, institutional effectiveness is the capability of the organization to acquire valuable resources to meet its needs. From the perspective of organizational psychology, institutional effectiveness is the extent to which an organization meets the needs of its members, and it is measured by the satisfaction of its members. From the perspective of organizational ecology, institutional effectiveness is the capability of the organization to adapt to the environment.

It is necessary to build an institutional environment conducive to the high-quality development of enterprises on the premise of improving the development and management levels of state-owned enterprises to promote the high-quality development of state-owned enterprises in the new era. [4] The State Grid Corporation of China has promoted the construction of the "One Body and Four Wings" development layout and made new arrangements for the development positioning, development goals, and key tasks of each business sector to accelerate the implementation of the strategic goal of building an internationally leading energy Internet enterprise with Chinese characteristics. The establishment of the assessment mechanism of institutional effectiveness not only is conducive to the formation of an organizational structure that supports "One Body and Four Wings" but also can further optimize the division of labor and synergy among the business sectors, achieving mutual complementarity, support, and empowerment and promoting the construction of the energy Internet company, thus maximizing the overall value of the company.

2 Establishment of an Assessment Model for Institutional Effectiveness

The pursuit of high-level economic development is one of the key characteristics of the economic development of China. For the State Grid Corporation of China, a novel power system is aimed to be realized with energy and power security as the fundamental premise, the power demands of economic and social development as the primary objective, and maximization of the consumption of new energy as the main task, a strong and smart grid as the platform, and the load-storage interaction of source and network and multi-energy complementarity as the support. These aspects require a rational reform of institutional efficiency as the basis.

2.1 Motivation for Institutional Effectiveness Assessment

First, the assessment can help respond to new challenges in the environment and organizational management. To achieve positive development and maintain sustainable success, external adaptability to the environment and business sensitivity should be maintained, and regular analysis and evaluation of organizational operations should be conducted internally so as to gain a sustainable competitive advantage through resource integration. Second, the assessment can help maintain the competitive advantage and healthy development of an organization. Organizational capability is a reflection of the efficiency and effectiveness of a company, and well-cultivated organizational capability is an important source of competitive advantage. Third, the assessment can help support the human resource strategy of the State Grid Corporation of China. Establishing and improving the indicator system and working mechanism of institutional effectiveness assessment and carrying out a comprehensive assessment of different levels and types of institutions form an essential layout of the 14th Five-Year Plan of the State Grid Corporation of China. The advantageous resources can be effectively integrated, and the development layout of "One Body and Four Wings" can be empowered with improved effectiveness through the study and practice of institutional effectiveness assessment.

2.2 Two Aspects of Institutional Effectiveness

Institutional effectiveness can be divided into the design aspect and the operation aspect. In the design aspect, the objectives need to be clarified, while in the operation aspect, the corresponding objects need to be selected. The clarification of objectives is to measure the performance of an institution in terms of the degree of achievement of strategic goals, the organizational management adaptability, the overall operation and management level, and the quality and effectiveness of human resource management, as well as to find the reasons for the shortcomings through the results so as to make continuous improvements. In the case of the selection of corresponding objects, the institutional effectiveness assessment is divided into the assessment of unit effectiveness and the assessment of internal institutional effectiveness. Based on the development layout of "One Body and Four Wings," the functional positioning, business characteristics, market environment, customer type, and other factors of each type of institution are analyzed and the common organizational characteristics are summarized to clarify the target of institutional effectiveness assessment and construct a typical assessment model and assessment dimensions.

2.3 Establishment of Institutional Effectiveness Model

2.3.1 Institutional Effectiveness Assessment Dashboard Model

This model applies to the power supply companies owned by the State Grid Corporation of China. The institutional effectiveness assessment dashboard divides the factors affecting institutional effectiveness into four dimensions: internal (internal control and communication and collaboration), external (target strategy and customer orientation), rigid (organizational structure and talent team), and flexible (culture building and reform and innovation) (see Figure 1). For each dimension, several aspects and specific assessment indicators are listed in detail. In the end, the red arrow points to the weakest link of institutional effectiveness.
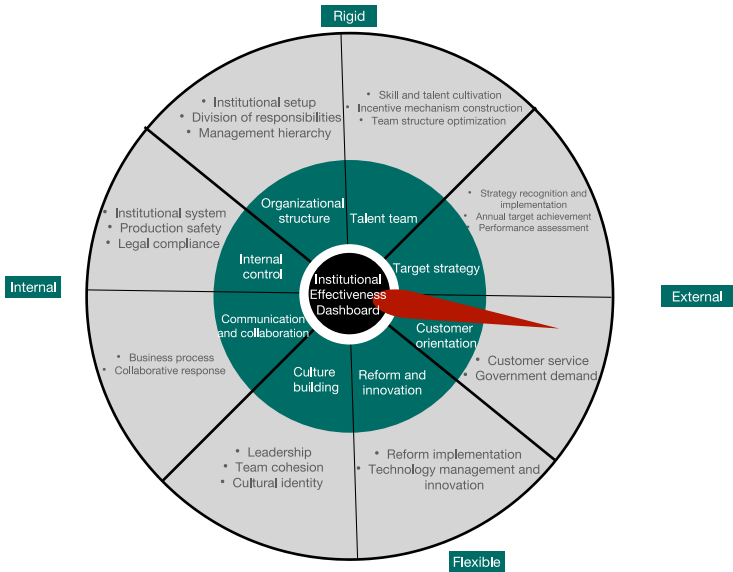
Figure 1. Institutional Effectiveness Assessment Dashboard Model

2.3.2 Six-Factor Model

This model is applicable to the marketized industrial and financial units owned by the State Grid Corporation of China. It has high requirements for implementing the company's "One Body and Four Wings" strategic layout with a focus on core business capability and sustainable innovation capability. This model can fully reflect external competition and greatly reflect the operation law of the market economy. The six factors involved in this model are strategic execution, market competitiveness, organizational flexibility, talent cohesion, customer influence, and cultural cohesion (see Figure 2). Among these, cultural cohesion is the basis; organizational flexibility, talent cohesion, and customer influence play a supportive role; and market competitiveness is the most prominent factor in the overall strategic execution of the organization.
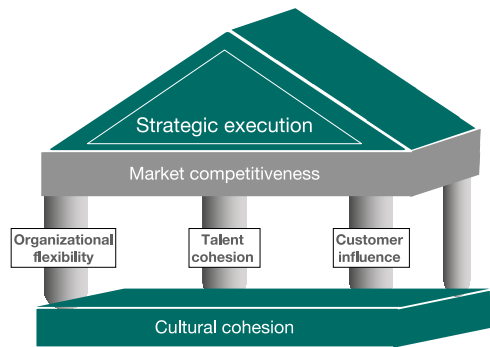
Figure 2. Institutional Effectiveness Six-Factor Model

2.3.3 Six-Box Model

This model applies to the strategic emerging business units owned by the State Grid Corporation of China. It is mainly used in the key businesses of energy Internet strategy and technology development, which may become a vital performance growth pole of the company. In this model, the management plays a critical role in enterprise development, and the strategic vision, top-level planning, innovation awareness, market sensitivity, and personality charm of management have direct impacts on enterprise development (see Figure 3). Therefore, centered on target positioning, this model focuses on the importance and impacts of leadership, business growth, synergy, team building, and support in promoting the development of strategic emerging industries and improving institutional effectiveness.

Figure 3. Institutional Effectiveness Six-Box Model

3. Values of Institutional Effectiveness Assessment

Technological and institutional innovation contributes to highly efficient economic growth toward maximizing the performance of various factor inputs, that is, maximizing profits with little inputs. Hence, the high-efficiency development of enterprises is the cornerstone of high-efficiency economic growth. However, the high-quality development of enterprises is essential to demonstrate good processes and results continuously. To achieve high-quality development, enterprises must build themselves into high-performance enterprises with high effectiveness for continuous growth and value creation; otherwise, they may only be short-lived. [5] In this case, the State Grid Corporation of China needs to use a rational indicator system and method to reasonably assess its own development and find the direction toward a high-performance enterprise so as to continuously inject vitality and vigor into the development of the market economy of China, thus promoting the high-quality development of the economy. Additionally, a tool has been developed to assess effectiveness, which is an entirely new trial for the State Grid Corporation of China. As the pilot progresses, the diagnostic results of the evaluation indicators can reflect the strengths that the enterprise has achieved and the weaknesses that the enterprise should pay more attention to and improve in the subsequent operations and management. This can help the enterprise to execute targeted management and continuously improve the operation and management level, thus achieving the development layout of "One Body and Four Wings."

4. Discussion and Conclusion

The ultimate goal of enterprise efficiency management is to implement management activities centering on how to improve organizational performance. An enterprise is a "function system" composed of multiple functions. Its operating mechanism can be regarded as a "mechanism system" composed of several internal sub-mechanisms, including dynamic mechanism and decision-making mechanism. Efficiency improvement is more important in state-owned enterprises due to the wide scope of business, multiple business models, relatively complex management structure, and other reasons.

This study took the organization effectiveness evaluation of the State Grid Corporation of China as the breakthrough point, according to the national grid and different types of enterprises, using the Institutional Effectiveness Assessment Dashboard Model, Six-Factor Model, and Six-Box Model. It provided a different solution, which was verified with multiple formats of large enterprises. It suggested that the development status of the enterprise should be assessed regularly using a scientific and effective system of enterprise performance evaluation, and high-quality development should be achieved based on the assessment results.

However, this study discussed only the enterprise efficiency management of the State Grid Corporation of China. The effect of the three enterprise efficiency management models used in this model in large enterprises was unclear. More cases and data of enterprise efficiency management should be collected in the future to discuss whether the management model and conclusion of this study are universally applicable.

References

[1] Peter Drucker. The Effective Executive [M]. New York: Harper and Row, 1996.
[2] Collins. Good to Great: Why Some Companies Make the Leap … And Others Don't, [M]Random House, London.2001.
[3] Chen C, Zhao S, Zhao H. C-Theory [M]. Beijing: Citic Press, 2004.
[4] Huang J, Xiao H, Wang X. Study on High-Quality Development of the State-Owned Enterprises [J]. China Industrial Economics, 2018 (10).
[5] Jim Collins, Morten T. Hansen. Good to Great [M]. Beijing: CITIC Press.

Analysis of Risk Factors of Fresh Agricultural Product Supply Chain Based on Grey Correlation Degree – Take Chengdu as an Example

Cheng WANG and Yonggang WU[1]

School of Logistics, Chengdu University of Information Technology, Chengdu 610103, Sichuan, China

Abstract. The purpose of this paper is to provide a reference for risk assessment and prevention of the fresh agricultural product supply chain in Chengdu. The risk factors of fresh agricultural products supply chain in Chengdu are empirically analyzed by using the grey correlation method, and the screening and sorting are carried out. According to the calculation results, it is concluded that the main risk factors are supply risk, logistics risk, demand risk, production risk, cooperation risk, etc., and the reference value provided can meet the status quo.

Key words. Fresh agricultural products, supply chain risk, risk factors, grey correlation degree

1. Introduction

Fresh agricultural products refer to the primary products produced by the agricultural sector without or with a little processing that cannot be stored for a long time at room temperature. Fresh agricultural products are generally divided into vegetables, fruits, meat, aquatic products and other types [1]. Fresh agricultural products have their own characteristics of freshness, seasonality, and perishability, coupled with the price fluctuations and uneven supply and demand of the agricultural product market itself, which lead to higher risks of fresh agricultural products and fragility and risk of the supply chain of fresh agricultural products.

Chengdu has produced a huge supply and demand market of fresh agricultural products. Although Chengdu has made a lot of efforts in the construction of fresh agricultural product supply chain in recent years, and achieved certain results, in the context of complex and changeable supply chain risks, as well as the emergence of new technologies and new models, quality and safety of fresh agricultural products and supply chain risks still occur from time to time [2]. Therefore, it is particularly important to identify and prevent supply chain risks.

A literature review was conducted on CNKI with the keyword "risk of supply chain of fresh agricultural products". Scholars have made certain achievements in the

---

[1] Corresponding Author, Yonggang WU, the School of Logistics, Chengdu University of Information Technology, China; Email: 2857844045@qq.com

identification of risk factors in the supply chain of fresh agricultural products, mainly covering the use of various methods to identify risk influencing factors. In terms of risk factor identification, Kramer et al. [3] defined the quality and safety risks of fresh fruit and vegetable supply chains as the following four: biological risks, chemical risks, physical risks, microbial risks; Deep et al. [4] used scenario planning to define future stable risks and analyze risk development; Siegel et al. [5] believed that the supply chain of agricultural products is derived from climate change, price fluctuation, quality issues, etc.; Juan et al. [6] concluded that the risk sources of emergencies are natural risk, market risk and production risk on the basis of analyzing the emergencies of fresh agricultural products. Willersinn et al. [7] believes that wholesalers, processors and retailers are the key to causing quantitative and quality risks in the Swiss potato supply chain. Li et al. [8] used the SCOR model and bibliometrics to identify risk factors in the supply chain of fresh agricultural products. Murtono et al. [9] used the Rapid Agricultural Supply Chain Risk Assessment (RapAgRisk) method to identify the risk of onion in the supply chain of fresh agricultural products; Peyman et al. [10] used the Failure Mode and Effects Analysis (FMEA) method to identify risk factors in the agricultural supply chain with three types of judgment indicators: severity, incidence, and detectability; Ming et al. [11] analyzed the risk factors affecting the supply chain of fresh agricultural products under "agricultural-supermarket docking" mode and "Internet +" mode. In the application of grey correlation degree to the identification of influencing factors of supply chain, Cheng et al. [12] identify the main influencing factors of agricultural product logistics by using grey relational degree; Ting et al. [13] used grey model to identify the risk factors of tourism supply chain; Yan et al. [14] used grey correlation degree to explore the influencing factors of agricultural product logistics in Shaanxi Province; Ge et al. [15] analyzed the influencing factors of the supply chain of fresh agricultural products by using gray correlation; Kun et al. [16] used ANP and grey correlation to identify the main influencing factors of the prefabricated building supply chain.

To sum up, although scholars have done a lot of research on the identification of risks in the supply chain of fresh agricultural products, they generally focus on subjective identification of risk sources or based on text statistics, and lack quantitative data analysis to determine risks. Combined with the grey model, this paper quantitatively analyzes the influencing factors of supply chain risk, sorts the risk factors, and summarizes the key risk factors affecting the supply chain.

Grey correlation analysis is one of the research methods of grey system theory [17], the main idea is to measure the degree of correlation of development trends among various factors [18]. In the development process of the system for a certain period, if the development trend and degree of the factors are closer, the degree of correlation of factors will be higher. Compared with other research methods, the data requirements for fresh agricultural products are higher, therefore, this paper uses the grey correlation method to determine the main risk factors among many risk factors according to the results of the correlation degree of each factor.

2. Risk factor analysis

This paper is based on the selection of factors affecting the supply chain of agricultural products by Yan et al. [19], Ming et al. [20], Rong et al. [21], and the current situation of the fresh agricultural product supply chain in Chengdu. The selection of indicators is based on systematic and scientific principles and selecting 34 indicators to analyze the

risk factors of the supply chain. This paper takes 2011 as the starting point and selects the data about 10 years for analysis. Taking the transaction volume of fresh agricultural products market in Chengdu as the reference sequence, Resident population, Gross Agricultural Product, Agricultural product logistics volume, Online retail sales of agricultural products and other indicators as the comparison sequence.

The main steps of grey correlation analysis are as follows:

(1) Determine the data analysis sequence; if there are m elements in the gray system, each element has n index attributes. Then the reference sequence is Y=Y (k)|k=1,2... m; the comparison sequence is Xi = Xi(k)| k = 1, 2... m, i = 1,2... n.

(2) Dimensionless processing of data; in this paper, the extreme value method is used to normalize the data of different dimensions in the system, and the formula is as follows:$Y = \frac{k-\min(k)}{\max(k)-\min(k)}$ k=1,2... m;$Xi = \frac{k-\min(k)}{\max(k)-\min(k)}$ k=1,2... m, i = 1,2... n

(3) Find the difference sequence; the formula is:$\Delta_i(k) = |Y^0(k) - X_i^0(k)|$.The difference between the two poles is: $\Delta_{max} = max_i max_k \Delta_i(k)$; $\Delta_{min} = min_i min_k \Delta_i(k)$

(4) Find the correlation coefficient; the formula is: $\xi_i(k) = \frac{\Delta_{min}+\rho\,\Delta_{max}}{\Delta_i(k)+\rho\,\Delta_{max}}$

(5) Calculate the degree of association; the formula for the degree of association r_i is:$r_i = \frac{1}{n}\sum_{k=1}^{m}\xi_i(k), i = 1,2\cdots n$

(6) Sorting the correlation degree; sort the comparison sequence $X_1 - X_n$ according to the calculation result of the correlation degree.

The Windows version of MATLAB (version R2018b, 9.5.0.944444) was used to load the data, write the code according to the model calculation formula in the MATLAB environment, and display the final calculation result.

3. Results and analysis

After dimensionless processing of the data, the correlation coefficients between the sequences calculated by the software are shown in Table 1.

The grey correlation degree of each risk factor to the risk of fresh agricultural product supply chain in Chengdu is shown in Table 2.

From the calculation results, the gray correlation degree of each risk influencing factor is between 0.70 and 0.98, above 0.9 are 19, and above 0.8 are 11, indicating that each risk influencing factor has an obvious effect on supply chain risk.

(1) Analysis of main influencing factors

Gross agricultural production has the greatest impact with a grey correlation of 0.98, ranking first, indicating that in the fresh agricultural product supply chain, the production and supply of products is very crucial.

The gray correlation degree of agricultural product logistics volume is 0.975, ranking second, in addition, trucks ranked fourth (0.96), freight turnover ranked eighth (0.938), and road mileage ranked ninth (0.934), which is enough to show that the circulation of fresh agricultural products is the most important part of the supply chain, there is also the storage scale of cold chain logistics (0.92) with a high degree of correlation, which is the key point of the circulation of fresh agricultural products [22].

The grey correlation degree of the total retail sales of consumer goods is 0.973, ranking third, in addition, the fifth-ranked per capita disposable income of residents (0.96) and the sixth-ranked permanent population (0.95) indicate that the market sales of

Table 1. Correlation coefficients between reference and comparative sequences of risk influencing factors

Risk factors	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Resident population (X1)	0.9422	0.9359	0.9300	0.9841	0.9994	0.9772	0.9513	0.9414	0.9354	0.9396
Resident per capita disposable income (X2)	0.9799	0.9987	0.9339	0.9103	0.9407	0.9948	0.9593	0.9767	0.9935	0.9607
Consumer Price Index (X3)	0.8618	0.8673	0.8644	0.9212	0.9412	0.9807	0.8975	0.8726	0.8598	0.8509
Commodity retail price index (X4)	0.8612	0.8685	0.8649	0.9199	0.9428	0.9800	0.8922	0.8746	0.8610	0.8543
Gross Agricultural Product (X5)	0.9956	0.9854	0.9802	0.9823	0.9928	1.0000	0.9817	0.9676	0.9775	0.9915
Production of fresh agricultural products (X6)	0.8852	0.8782	0.8941	0.9425	0.9514	0.9688	0.8962	0.8867	0.8764	0.8709
Cargo volume (X7)	0.8304	0.7748	0.8714	0.9534	0.9784	0.9195	0.8554	0.8556	0.8664	0.8820
Cargo turnover (X8)	0.9426	0.8959	0.9369	0.9502	0.9684	0.9614	0.9060	0.9123	0.9455	0.9692
Agricultural product logistics volume (X9)	0.9860	0.9802	0.9627	0.9850	0.9912	0.9823	0.9567	0.9799	0.9503	0.9815
Truck (X10)	0.9991	0.9792	0.9431	0.9794	0.9888	0.9630	0.9143	0.9562	0.9968	0.9362
Highway Mileage (X11)	0.9301	0.9139	0.9039	0.9535	0.9706	0.9992	0.9208	0.9201	0.9088	0.9223
Warehouse scale of cold chain logistics (X12)	0.9271	0.9313	0.9527	0.9519	0.8494	0.9714	0.9955	0.9978	0.9639	0.7025
Basic information on post and	0.8062	0.8251	0.8425	0.8500	0.8753	0.8652	0.7992	0.8921	0.6878	0.5573
Number of comprehensive retail markets for Internet users (X15)	0.9220	0.8743	0.8106	0.8428	0.8726	0.9415	0.8855	0.8260	0.7917	0.7965
	0.9839	0.9596	0.9456	0.9900	0.9923	0.9819	0.9277	0.9282	0.9259	0.8945
The number of mobile phones used (X16)	0.9397	0.9082	0.8913	0.9571	0.9744	0.9766	0.9395	0.9483	0.8863	0.9199
Agricultural Science and Technology Expenditure (X17)	0.9976	0.9541	0.8791	0.9237	0.8941	0.9562	0.9085	0.8880	0.9325	0.9578
Crop Affected Area (X18)	0.5850	0.5997	0.5355	0.9737	0.8098	0.7874	0.6619	0.7189	0.6677	0.7327
Rainfall (X19)	0.8821	0.9564	0.7682	0.9389	1.0000	0.9614	0.8757	0.9604	0.8722	0.9248
Sunshine Hours (X20)	0.9216	0.8922	0.9782	0.3336	0.8834	0.8282	0.7798	0.7672	0.6986	0.7117
Fiscal Expenditure on Transportation (X21)	0.9034	0.8199	0.8217	0.7947	0.7944	0.9676	0.8436	0.8099	0.8673	0.8075
Government investment in agricultural science and technology (X22)	0.9294	0.9061	0.8247	0.9442	0.9232	0.9924	0.8810	0.9860	0.9526	0.9842
Agricultural and livestock products wholesale enterprises (X23)	0.8937	0.9486	0.8878	0.9204	0.9197	0.9160	0.7973	0.7793	0.9915	0.8602
Income from agricultural and sideline food processing industry (X24)	0.9478	0.9274	0.8807	0.9243	0.9213	0.8979	0.9534	0.8256	0.8234	0.8499
Number of college graduates (X25)	0.9390	0.9330	0.8965	0.9305	0.9425	0.9727	0.9270	0.9143	0.9054	0.9234
Total power of agricultural machinery (X26)	0.9375	0.9230	0.8965	0.9227	0.9365	0.9961	0.9349	0.8896	0.9005	0.8940
Grain primary processing machinery (X27)	0.9142	0.9065	0.9004	0.9535	0.9785	0.9754	0.9357	0.9191	0.8970	0.8820
Total inventory of agricultural products at the end of the year (X28)	0.8306	0.8749	0.9484	0.9491	0.9637	0.9428	0.8870	0.8531	0.9025	0.9764
Online retail sales of agricultural products (X29)	0.7874	0.8122	0.8178	0.8273	0.9605	0.9473	0.9122	0.8971	0.7809	0.5766
Price index of agricultural production tools (X30)	0.8301	0.8493	0.8773	0.9268	0.9513	0.9647	0.8859	0.8882	0.8347	0.8601
Total retail sales of social consumer goods (X31)	0.9259	0.9670	0.9914	0.9887	0.9947	0.9834	0.9875	0.9830	0.9454	0.9705
Agricultural fertilizer application (X32)	0.7806	0.7746	0.7667	0.8152	0.8241	0.8773	0.8079	0.7865	0.7590	0.7408
Pesticide usage (X33)	0.8396	0.8470	0.8576	0.9176	0.9457	0.9834	0.9139	0.8739	0.8269	0.7963

Table 2. Grey correlation degree of risk factors affecting fresh agricultural product supply chain in Chengdu

Risk factors	X1	X2	X3	X4	X5	X6	X7
Correlation	0.954	0.965	0.891	0.891	0.985	0.905	0.878
Risk factors	X8	X9	X10	X11	X12	X13	X14
Correlation	0.939	0.976	0.965	0.934	0.924	0.8	0.856
Risk factors	X15	X16	X17	X18	X19	X20	X21
Correlation	0.953	0.934	0.929	0.707	0.914	0.78	0.843
Risk factors	X22	X23	X24	X25	X26	X27	X28
Correlation	0.932	0.891	0.895	0.928	0.923	0.926	0.912
Risk factors	X29	X30	X31	X32	X33		
Correlation	0.832	0.887	0.973	0.793	0.88		

fresh agricultural products and consumption of fresh agricultural products by residents have a greater impact on supply chain risks.

(2) Screen for risk factors

After analyzing the grey correlation degree of 34 risk factors, considering the data and its actual situation, the last three rankings (X32, X20, X18) were eliminated with a correlation lower than 0.8. The remaining 31 risk factors that are closely related can be used as a reference for the secondary index system for risk assessment and prevention of fresh agricultural product supply chain in Chengdu.

In addition, according to the meaning represented by the index data, this paper summarizes the risk factors X1-X4 as demand risk, X5-X6 as supply risk, X7-X12 as logistics risk, X13-X17 as information risk, X18-X20 as environmental risk, X21-X22 as policy risk, X23-X25 as cooperation risk, X26-X27 as production risk, X28-X31 as market economic risk, and X32-X33 as quality risk. The findings are closely related to

studies such as Qing [23], Cui [24]. On this basis, the average value of the correlation degree of each classification index is calculated and ranked, and the first-level discriminant index of the supply chain risk of fresh agricultural products in Chengdu is obtained, as shown in Table 3.

Table 3. The first-level discriminant index of risk in the supply chain of fresh agricultural products

First-level indicator	Risk factors	Correlation	Ranking
supply risk	X5-X6	0.95	1
Logistics risk	X7-X12	0.94	2
demand risk	X1-X4	0.93	3
production risk	X26-X27	0.92	4
Cooperation risk	X23-X25	0.91	5
Market economic risk	X28-X31	0.90	6
information risk	X13-X17	0.89	7
policy risk	X21-X22	0.89	8
quality risk	X32-X33	0.84	9
Environmental risk	X18-X20	0.80	10

4. Conclusion

On the basis of existing research, this paper collects relevant data on the supply chain of fresh agricultural products in Chengdu, uses the grey correlation model to analyze the risk factors, and selects and sorts the risk factors according to the results. According to the calculation results, it is concluded that the main risk factors are supply risk, logistics risk, demand risk, production risk, cooperation risk and so on.

References

[1]   Xiang WX., Li Z., Xin LJ. Research on the risk of O2O fresh agricultural supply chain, 4th International Symposium on Social Science (ISSS 2018).
[2]   Zhang P, Chen Z, Cao W. Research on supply chain coordination of fresh agricultural products under agricultural insurance, MATEC Web of Conferences. 2017; p100.
[3]   Kramer E. Improving the safety of fresh fruit and vegetables, Risk Management in the Supply Chain. 2005; p179-228.
[4]   Deep A, Dani S. Managing global food supply chain risks: a scenario planning perspective. POMS 20th Annual Conference; 2009.
[5]   Siegel P, Jaffee S, Rews C. Rapid agricultural supply chain risk assessment: a conceptual framework; 2010.
[6]   Willersinn C, Mack G, Mouron P. Quantity and quality of food losses along the Swiss potato supply chain: Stepwise investigation and the influence of quality standards on losses, Waste Management, 46(DEC). 2015; p120-132.
[7]   Juan X, Ting LX, Tao TT, Ze BY. Research on the emergency organization model of farmers' risks in fresh agricultural products emergencies, Journal of Huazhong Agricultural University (Social Science Edition). 2013; (03):64 -70.
[8]   Zhang L. Research on risk management of fresh agricultural products supply chain, Shijiazhuang Railway University; 2018.
[9]   Murtono Y, Ushada M, Suwondo E. Shallot supply chain analysis using rapid agricultural supply chain risk assessment method: case in Bantul Regency, Special Region of Yogyakarta, Indonesia, IOP Conference Series: Earth and Environmental Science. 2019; p355.
[10] Zandi P, Rahmani M, Khanian M. Agricultural risk management using fuzzy TOPSIS Analytical Hierarchy Process (AHP) and Failure Mode and Effects Analysis (FMEA), Agriculture. 2020; 10(11):504.

[11] Ming M. Supply chain analysis and control optimization of fresh agricultural products, Business News. 2020; (31):135-136.
[12] Cheng DZ. Grey correlation analysis of agricultural product logistics and its influencing factors, Systems Engineering. 2012; 30(10): 123-126.
[13] Ting YL, Jun CL. Analysis of risk factors of tourism supply chain based on grey model, China Business Review, (Z1). 2015; p102-104.
[14] Yan X. Agricultural product logistics and its influencing factors in Shaanxi Province based on grey correlation analysis, Liaoning Agricultural Science. 2019;(04): 26-28.
[15] Ge Z. Research on the influencing factors of fresh agricultural product supply chain based on grey correlation analysis, Wuhan University of Light Industry; 2020).
[16] Kun WQ, Lei DH, Xiong SC, Ke Z. Research on the influencing factors of the flexible supply chain of prefabricated buildings, Construction Economy. 2021;42(10): 79-82.
[17] Long DJ. The basic method of Chinese-English contrasting grey system, Huazhong University of Science and Technology Press; 2005.
[18] Tzong RL, Hsing WW, Hsiang HY. The feasibility study of promotion activities in farmers' markets with regional agricultural products, Int. J. of Logistics Economics and Globalisation. 2018;7(3): 248-267.
[19] Yan X. Agricultural product logistics and its influencing factors in Shaanxi Province based on grey correlation analysis, Liaoning Agricultural Science. 2019; (04): 26-28.
[20] Heming D. Analysis of influencing factors of agricultural product logistics in my country based on grey correlation degree, Hebei Enterprise. 2018;(12):107-109.
[21] Rong ML, Chou MD, Yuan ZE. Grey correlation analysis of the influence of main agricultural logistics factors on agricultural development: Taking Gansu Province as an example, Productivity Research. 2014; (01):67-71+81.
[22] Zhang LH. Application of IoT in the supply chain of the fresh agricultural products. ACSR ADV COMPUT;2016.
[23] Qing ZL, Zhong Z. Research on risk identification and prevention of fresh agricultural product supply chain, Logistics Engineering and Management.2021; 43(02): 52-55.
[24] Cui W, Feng PY. Risk assessment of the supply chain of fresh agricultural products in Anhui Province, Journal of Wuyi University. 2021; 40(09): 45-50.

Development Status and Trend Analysis of Internet of Medical Things Industry in China

Jian JIAO [a, 1]

[a] *Institutes of Science and Development, Chinese Academy of Sciences, P. R. China*

Abstract. This article analyzes the development status, development trend and prospects of China's Internet of Medical Things (IoMT) industry from a macro perspective. Our survey mainly includes: analyzing the necessity and urgency of China's medical system reform from the various dilemmas faced by China's medical system, and analyzing the development of the IoMT industry based on the current basic conditions of development of the Internet of Things (IoT), information technology and background of COVID-19 epidemic. Opportunities and the evolution of China's IoMT policy were also analyzed. Moreover, from the five aspects of medical industry informatization, Internet hospitals, smart wearable devices, medical AI industry and medical industry digitization, the development status and trends of China's IoMT industry are analyzed. Finally, it looks forward to the development prospects and directions of IoMT industry for health care in China.

Keywords. IoMT, China's medical system, development status, health care

1. Introduction

Internet of Medical Things (IoMT) generally refers to all medical treatment and market behaviors carried out by the Internet platform and the concept of Internet of Things (IoT) [1-2]. The subjects of behavior include Internet companies, hospitals, insurance companies, doctors, patients, and other users with medical and health management needs. The purpose of "nodes" is to accurately match patient groups and obtain accurate and comprehensive health information through the combination of the Internet, enhance health services and information transparency, enhance the interconnection of various elements of medicine and health, and achieve the effect of precision medical treatment [3]. In brief, this article analyzes the difficulties faced by China's medical system, analyzes the development opportunities, policy evolution, development status and development trends of China's IoMT industry from a macro level, and looks forward to the future development prospects of IoMT in China.

---

[1] Corresponding Author, Institutes of Science and Development, Chinese Academy of Sciences, P. R. China; E-mail: jiaojian@casisd.cn.

2. Difficulties and problems of China's medical system

2.1. Medical resources are unevenly distributed in the east and west of China with uneven distribution of good and bad

According to public data from the 2019 China Health Statistics Yearbook, the total number of Third-class hospitals in eastern medical institutions and the number of tertiary hospitals is significantly more than those in the central and western regions. Moreover, the total number of health technicians and practicing doctors in the eastern region have absolute advantages over the central and western regions. In general, the total medical resources and high-quality medical resources in the east have significant advantages. In terms of regions, the difference between urban and rural areas cannot be underestimated. High-quality medical resources are basically concentrated in cities. According to data from the National Bureau of Statistics, rural basic medical resources are in vain, and it is difficult to meet the health and medical needs of the vast rural population.

2.2. Excessive medical treatment exists, and the balance of screening and measurement mechanisms has not yet been reached

According to estimates by the World Health Organization (WHO), the global health sector spends US$7.1 trillion each year, of which 20%-40% is wasted in technical means or strategies that are not optimal or unnecessary in terms of cost-effectiveness, that is, the ratio of input to output is not the best way. In China, over-medicine exists for a long time due to problems such as "medicine to support doctors", relatively lagging medical concepts, and distrust between doctors and patients. For example, in 2017, the journal "Lancet" pointed out that China has problems with the abuse of antibiotics and the high rate of cesarean section [4]. Therefore, how to make better use of medical resources and avoid excessive medical treatment will have more practical significance for China.

3. Opportunities for the development of IoMT industry in China

3.1. Combine IoT to build a patient-centered hierarchical diagnosis and treatment platform

As the highlight of China's medical reform, hierarchical diagnosis and treatment means that medical institutions at all levels in China classify various diseases according to the severity of the disease and the difficulty of treatment, and undertake the treatment of diseases of different levels. Under the hierarchical treatment system, common diseases are mostly diagnosed and treated in first-level medical institutions, chronic diseases are often diagnosed and treated in second-level medical institutions, and difficult or critical diseases are treated in third-level large-scale comprehensive medical institutions.

Based on this, the realization of hierarchical diagnosis and treatment must face up to and solve two major dilemmas: on the one hand, the flexible use of IoT to allocate medical resources, so that doctors can flow between the community and the hospital, and further realize the reasonable distribution of doctor resources; on the other hand,

reasonably use the Internet of Things for patient diversion and treatment, implement patient-centeredness, and allow medical resources to be used rationally [5].

3.2. The COVID-19 epidemic boosts the development of IoMT industry

During the COVID-19 pandemic, people were forced to stay at home, and the advantages of digital medical care have gradually emerged, such as more convenient online services, more doctor resources in departments, and at the same time avoiding the risk of nosocomial infection [6-8]. During the epidemic period of home isolation and tight medical resources, patients' demand for online medical services is rapidly increasing due to the consideration of reducing the probability of nosocomial infection.

3.3. New technologies accelerate the digital transformation of healthcare and medicine

The acceleration of China's new infrastructure and the rapid development of 5G, cloud computing, big data, IoT, artificial intelligence, blockchain, virtual reality and other technologies have injected a "cardiotonic agent" into the development of the IoMT industry. In the post- COVID-19 epidemic era, digital technology has come to the forefront and has become an emerging force driving the digital transformation and upgrading of China's medical and pharmaceutical industries [9].

4. The policy evolution of IoMT in China

Overall, China's IoMT policies have mainly experienced three stages: the promotion period, the austerity period and the standardization period, and they are gradually embodying the characteristics of standardization, top-levelization, and clarity. Especially since 2018, policies in the national IoMT field have been intensively introduced, and various provinces and cities are also accelerating the construction of provincial-level internet medical service supervision platforms (Table 1).

Table 1. Policies related to IoMT of China in recent years.

Date	Name of Policy
September 2005	Interim Provisions on the Approval of Internet Drug Transaction Services
October 2013	Notice on Strengthening the Administration of Internet Drug Sales
August 2014	Opinions on the Promotion of Telemedicine Services in Medical Institutions
July 2015	Guiding Opinions on Actively Promoting the "Internet +" Action
January 2017	"Thirteenth Five-Year" Hygiene and Health Plan
July 2018	Trial Implementation of Internet Hospital Management Measures
September 2018	National Health and Medical Big Data Standards, Safety and Service Management Trial Measures
February 2020	Notice on Internet Diagnosis and Treatment Consultation Services in the Prevention and Control of COVID-19 epidemic
March 2020	Guiding Opinions on Promoting the Development of "Internet+" Medical Insurance Services During the Period of Prevention and Control of COVID-19 epidemic
April 2020	Regarding the Implementation Plan for Advancing the "Data Empowered AI" Action and Cultivating New Economic Development

The policy promotion period is from 2014 to 2015 year. In August 2014, the National Health Commission of the People's Republic of China issued the "Opinions on Promoting Telemedicine Services in Medical Institutions", encouraging localities to establish telemedicine service platforms. In July 2016, National Medical Products Administration notified Hebei Province, Shanghai, and Guangdong Province to end the pilot work of drug online retail on third-party Internet platforms. In April 2017, the state suspended the use of names such as "Internet Hospital", "Cloud Hospital", and "Network Hospital". From 2018 to 2019, IoMT has entered a period of policy regulation. In August 2019, National Healthcare Security Administration issued the "Guiding Opinions on Improving Internet + Medical Service Prices and Medical Insurance Payment Policies", which included Internet + medical services into the scope of medical insurance payment for the first time.

5. Development status and trend of IoMT industry in China

IoMT is closely related to the development of the Internet itself. In general, China's IoMT has gone through an era dominated by PC mutual and mobile Internet, and is currently in the transitional stage of transitioning to Internet hospitals. Eventually, comprehensive IoMT care will be realized, including services such as online consultation, diagnosis, remote treatment, prescription, and delivery of medicines to home. At present, China's IoMT industry has integrated many participants such as mobile medical service providers, medical equipment manufacturers, IT giants, venture capital, mobile operators, application developers, data companies, and insurance companies, forming an IoT-based healthcare industry. And, the industrial structure dominated by insurance and online medical care [10].

In recent years, with favorable policies, technological progress, and increased residents' health awareness, China's IoMT market has developed rapidly, with a compound annual growth rate of more than 30%. According to our survey and research, the market size of China's IoMT has reached 41 billion RMB in 2020 (Figure 1).
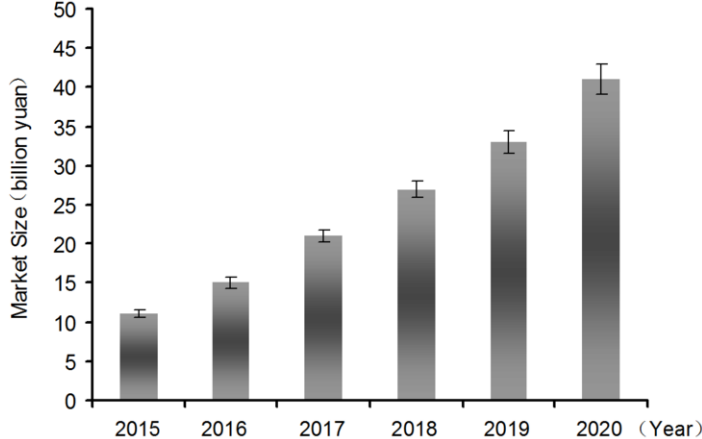
Figure 1. The market size of China's IoMT from 2015 to 2020

5.1. Informatization of medical industry

Hospitals are the main target of medical informatization. The IT system built around hospital informatization supports medical care, medical insurance, and medicine respectively, and is the main link of medical informatization. Among them, medical IT is the core, mainly including hospital management system, image archiving and management system, hierarchical diagnosis, and treatment platform, etc. Most of the major enterprises that carry hospital informatization are concentrated in established medical software and hardware companies, which have inherent advantages in hospital resources. As the technical level and level requirements of medical information systems become higher and higher, small and medium-sized manufacturers with average technical strength and low product reliability will be gradually eliminated. At present, the competitive landscape of the domestic medical informationization market will gradually move closer to mature markets, and industry concentration will gradually increase [11].

5.2. Internet hospital

Internet hospitals are the online model of physical hospitals. According to the "Internet Hospital Management Measures (Trial)" issued by National Health Commission in September 2018, Internet hospitals must have physical medical institutions as offline support, and the setting of departments and diagnosis and treatment subjects that Internet hospitals can carry out shall not exceed the physical medical care they rely on. Our survey found that among the more than 100 Internet hospitals nationwide in 2019, hospital-led Internet hospitals accounted for 41%, and enterprise-led Internet hospitals accounted for 59%. During the COVID-19 epidemic, the rapidly growing demand for home consultations, and the promulgation of multiple policies by relevant authorities, have made Internet hospitals get multiple benefits [12].

5.3. Smart wearable device

The gap between China's medical supply and demand has brought new opportunities for wearable medical devices. Wearable medical equipment has a bright future. The main reasons are as follows: on the one hand, China's aging population has caused a rapid increase in medical demand; on the other hand, China's medical resources are seriously short of supply, especially in remote areas. In the future, patients with chronic diseases such as coronary heart disease, hypertension, and diabetes will not only receive drug treatment, but also receive overall disease management programs including remote monitoring, remote treatment program adjustment, lifestyle management, and wearable drug delivery. At present, China's medical wearable devices are still in the initial stage of development. It is foreseeable that smart wearable devices rely heavily on big data infrastructure and network operations. Quickly accumulating users and obtaining user health data is the primary issue, and data issues will become industry barriers [13].

5.4. Medical AI industry

In recent years, China's smart medical market demand has continued to grow, and the market scale has expanded rapidly, and it has become the world's third largest smart

medical market after the United States and Japan. Our survey found that as of March 2021, China has 2,245 companies involved in the medical AI business, including 19 listed companies. Among them, judging from the research direction and layout of enterprises in Jiangsu, Zhejiang and Shanghai (about 143), medical imaging and auxiliary diagnosis and treatment are the two most popular directions. There are a total of 45 AI companies assembled, accounting for more than 30% of the entire AI market share. But at the same time, there are still many companies heading towards chatbots, disease risk prediction, drug discovery, and health management. Overall, the segmented track of Chinese medical AI companies presents a decentralized competition.

5.5. Digitalization of medical industry

Digitization is the foundation of IoT, including the procurement of medical laboratory equipment, reagents and consumables, technical outsourcing service customization, to intermediate links such as consultation, appointment, diagnosis, treatment, medication and rehabilitation, to the delivery of final products, services, and medical insurance [14]. At present, the degree of digitalization of the supply-side and demand-side enterprise management of medical elements is relatively low, which is a key transformation link of the medical industry chain [15-16]. The industrial Internet of Things platform will be an important driver of digitalization, and gradually realize the digitalization of procurement, digitalization of production, digitalization of management, digitalization of marketing, and transactions.

6. Conclusion and Prospects

With the integration and application of IoT technology for health care, 5G communication networks, AI technology, big data, cloud computing and other intelligent technologies, and a new generation of information technology in Internet medical care, the IoMT industry will form functions such as "sensing-connection-convergence-integration-analysis-decision-making". The linked system support system promotes the gradual upgrade and maturity of Internet medical application scenarios that are characterized by intelligence, networking, remoteness, and mobility, and accelerates the process of large-scale applications [14].

The IoMT industry in China will enter a period of rapid growth of intelligent, efficient, and large-scale development. In the future, IoMT will become a "new kinetic energy" to promote the rapid development of China's digital economy. At the terminal level, intelligent medical equipment and terminal equipment will accelerate the popularization and application, which is concentrated in wireless intelligent diagnosis and treatment equipment and wearable intelligent monitoring equipment. At the network layer, 5G application scenarios are adapted to the needs of wireless medical and health scenarios, and enhanced mobile broadband can provide emergency vehicles with continuous wide-area coverage and achieve "getting on the car and entering the hospital". At the platform level, technologies such as cloud computing, big data, artificial intelligence, and blockchain will promote the transformation and upgrading of medical information and telemedicine platforms. At the application level, 5G medical applications have unlimited potential, and intelligence and personalization are the two major development directions [17-18].

In general, China's IoMT industry is still in the exploratory stage. However, judging from the rapid development in recent years, whether it is driven by market demand or the inevitable result of technological progress and integration, IoMT industry still needs to be human-centric and data-driven. While improving the effectiveness of medical treatment, only by identifying medical pain points can medical services better meet people's health needs.

References

[1] Alqaralleh BAY, Vaiyapuri T, Parvathy VS, et al. Blockchain-assisted secure image transmission and diagnosis model on Internet of Medical Things Environment. Pers. Ubiquit. Comput. 2021: https://doi.org/10.1007/s00779-021-01543-2.

[2] Bajaj A, Bhatnagar M, Chauhan A. Recent trends in internet of medical things: a review. Advances in Machine Learning and Computational Intelligence. Algorithms for Intelligent Systems. Springer, Singapore. 2012: https://doi.org/10.1007/978-981-15-5243-4_61.

[3] Ding Y, Wu GZ, Chen DJ, et al. DeepEDN: A deep learning-based image encryption and decryption network for Internet of Medical Things. IEEE Internet Things. 2021; 8(3): 1504-1518.

[4] Yang XJ, Sun SS. Comparison of maternal and fetal complications in elective and emergency cesarean section: a systematic review and meta-analysis. Arch. Gynecol. Obstet. 2017; 296: 503–512.

[5] Deebak BD, Al-Turjman F. Smart mutual authentication protocol for cloud based medical healthcare systems using Internet of Medical Things. IEEE J. Sel. Areas Commun. 2021; 39(2): 346–360.

[6] Ahmad S, Ali N, Kausar M, et al. Road toward rapid molecular point of care test to detect novel SARS-coronavirus 2019 (COVID-19): review from updated literature. Allergol. Immunopath. 2020; DOI: 10.1016/j.aller.2020.06.001.

[7] Fabiani L, Saroglia M, Galata G, et al. Magnetic beads combined with carbon black-based screen-printed electrodes for COVID-19: A reliable and miniaturized electrochemical immunosensor for SARS-CoV-2 detection in saliva-ScienceDirect. Biosens. Bioelectron. 2020; DOI: 10.1016/j.bios.2020.112686.

[8] Lin B, Wu SJ. COVID-19 (Coronavirus Disease 2019): Opportunities and challenges for digital health and the Internet of Medical Things in China. Omics: J. Integra. Biol. 2020; DOI:10.1089/omi.2020.0047

[9] Al-Turjman F, Nawaz MH, Ulusar UD. Intelligence in the Internet of Medical Things era: a systematic review of current and future trends. Comput. Commun. 2019; DOI: 10.1016/j.comcom.2019.12.030.

[10] Joyia GJ, Liaqat RM, Farooq A, et al. Internet of medical things (IOMT): applications, benefits and future challenges in healthcare domain. J. Commun. 2017; 12: 240-247.

[11] Arthur G, Youakim B, Bertrand M, et al. Internet of Medical Things: A review of recent contributions dealing with cyber-physical systems in medicine. IEEE Internet Things. 2018; DOI: 10.1109/JIOT.2018.2849014.

[12] Manogaran G, Chilamkurti N, Hsu CH, et al. Emerging trends, issues, and challenges in Internet of Medical Things and wireless networks. Pers. Ubiqui. Compu. 2018; DOI: 10.1007/s00779-018-1178-6.

[13] Basatneh R, Najafi B, Armstrong DG. Health sensors, smart home devices, and the Internet of Medical Things: an opportunity for dramatic improvement in care for the lower extremity complications of diabetes. J. Diabetes Sci. Technol. 2018; DOI: 10.1177/1932296818768618.

[14] Oniani S, Marques G, Barnovi S, et al. Artificial intelligence for Internet of Things and enhanced medical systems. 2021; ISBN: 978-981-15-5494-0.

[15] Gupta D, Gupta U. On robust asymmetric Lagrangian ν-twin support vector regression using pinball loss function. Appl. Soft Comput. 2021; DOI: 10.1016/j.asoc.2021.107099.

[16] Gupta U, Gupta D. On Regularization Based Twin Support Vector Regression with Huber Loss. Neural Process. Lett. 2021; DOI: 10.1007/s11063-020-10380-y.

[17] Balasubramanian V, Jolfaei A. A scalable framework for healthcare monitoring application using the Internet of Medical Things. Softw. Pract. Exper. 2020; DOI: 10.1002/spe.2849.

[18] Gao L, Liu L, Zhang J, et al. Building of smart home medical system based on Internet of Things. Internet Things Cloud Comput. 2016; DOI: 10.11648/j.iotcc.20160403.14.

A Multiprocessing Framework for Heterogeneous Biomedical Embedded Systems with the Proposal of a Finite State Machine-Based Architecture

Xiaohe TIAN[1] and Mang I VAI
Faculty of Science, University of Macau, Macao, China

Abstract. The applications of heterogeneous embedded systems for biomedical engineering are promising, as quick response of biomedical systems is often required due to the life-saving nature of biomedical engineering, and multiple devices with completely different cores and designs can be involved in a single patient. In this paper, we propose a multiprocessing framework and then, with regard to the framework, we propose an architecture for heterogeneous embedded systems that uses finite state machines (FSMs). A multithreading method on an electrocardiogram (ECG) software is implemented as the verification of our framework.

Keywords. Multiprocessing framework, heterogeneous embedded systems, finite state machine.

1. Introduction

Embedded systems play an important role in biomedical systems due to their response speed, reliability, portability, and ability to be designed for a specific biomedical use. Meanwhile, heterogeneous multi-core embedded systems take advantage of not only their potential in reducing power consumption, but the variety of techniques and cores used by biomedical devices for different patients and diagnoses. Therefore, we consider these two problems of (1) how embedded systems should be configured for specific biomedical uses, and (2) how we can improve the efficiency of the systems.

At the side of biomedical system configuration, T. Hussain et al. developed a Biomedical Application Processing System which made use of both dual-core processor and Biomedical Application Specific Reconfigurable Accelerator (BASRA) [1]. Then, at the side of system efficiency, G. Xie et al. proposed models for hardware cost, reliability requirement (RR) and real-time requirement assessments, and then introduced exploratory hardware cost optimization (EHCO) algorithm with its derived algorithms, EEHCO and SEEHCO [2]. While those works give specific ideas about efficiency improvement and biomedical applications potentially feasible for embedded systems, we try to incorporate those ideas, among others, by introducing a

---

[1] Corresponding author, Department of Electrical and Computer Engineering, University of Macau, E11, Avenida da Universidade, Taipa, Macau, China; E-mail: mb85468@um.edu.mo.

multiprocessing framework and then, with regard to the framework, proposing an architecture for heterogeneous embedded systems that uses finite state machines (FSMs). The framework will be introduced in Section II, while the architecture proposal will be introduced in Section III. Then, as a verification to the framework and architecture, a multithreading method on an electrocardiogram (ECG) software is implemented in Section IV. We conclude in Section V.

2. Multiprocessing Framework

We propose a multiprocessing framework as this: for an application which executes every input through a fixed set of tasks, we divide it into processing units of finite number. The tasks assigned to each of the units are also fixed, so that they can form a task dependency graph (TDG) that is a directed acyclic graph (DAG). Examples of TDGs, one DAG and the other non-DAG, are shown in Figure 1.

We propose this framework with considerations on (1) efficiency, so that time wasted through task switching can be reduced and memory access schemes can be simplified, with every processing unit administrating a fixed set of tasks; (2) simplicity and flexibility, so that manual segmentations of tasks are possible in the absence of automatic task segmentation schemes, with the number of processing units being finite; (3) availability for real-time applications.
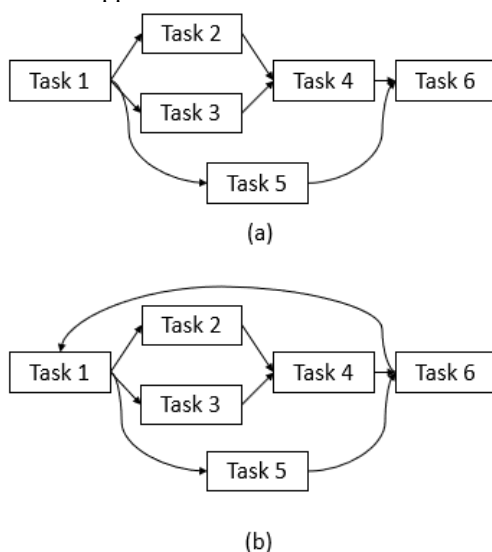
Figure 1. Examples of task dependency graphs (TDGs) from the perspective of a single input. Here, every box represents a set of tasks enclosed in a processing unit, and every edge represents a dependency between two sets of tasks. In (a), no edges form cycles, and hence it is a directed acyclic graph (DAG), while for (b), because of the extra dependency from Task 6 to Task 1, Tasks 1-2-4-6-1 form a loop, and the graph is not a DAG.

If the TDG is a DAG, all processing units can execute tasks in parallel, and both multiprocessing schemes, namely concurrent processing and parallel processing, can be used in accordance with the TDG. However, in case the processing units are not already well-defined or the dependencies of tasks in them cannot form a DAG, task

segmentation schemes need to be proposed. The difficulty comes at making the TDG a DAG. As illustrated in Figure 1 (b), any cycle formed in a TDG will make parallel processing unavailable. Makeshift methods, such as altering the algorithm and using extra memory for breaking the cycles of task dependencies, can be applied for making up DAGs, while efficient and automatic methods for breaking the cycles of dependencies are subject to further research.

3. Embedded System Architectures

With our multiprocessing framework, we propose an architecture for embedded systems, aiming at taking advantage of the framework. An overview of the proposed architecture is given in Figure 2. As it shows, every processor has a finite state machine (FSM) attached to it, and a memory space for data access and storage. There is also a simple data processing unit (DPU), which contains concurrent processor algorithms, a memory supervisor as a centralized controller for the memory spaces of processors, and the necessary memory space for DPU itself. FSMs communicate with other components by sending and receiving signals. Here in this figure, reading request (R_r) and writing request (W_r) signals that FSMs send to DPU, as well as reading finished (R_f) and writing finished (W_f) signals that DPU sends to FSMs, are presented.
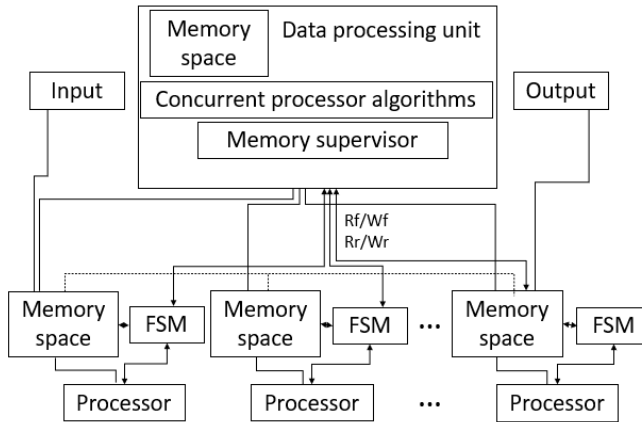
Figure 2. Proposed embedded system architecture based on our framework. Unarrowed edges indicate the communications between those components are by data passages or supervisions. Arrowed edges indicate the communications are by transitory signals. Dotted edges indicate the communications may exist but are dependent on other conditions.

Figure 3 (a) and (b) show our proposed FSMs, namely FSM1 and FSM2. FSM1 is used for all processors except terminal processor(s), which are processors with no "next processors", i.e., no processors dependent on them. An example is Task 5 in Figure 1 (a). Terminal processors use FSM2 because they do not need a waiting state.
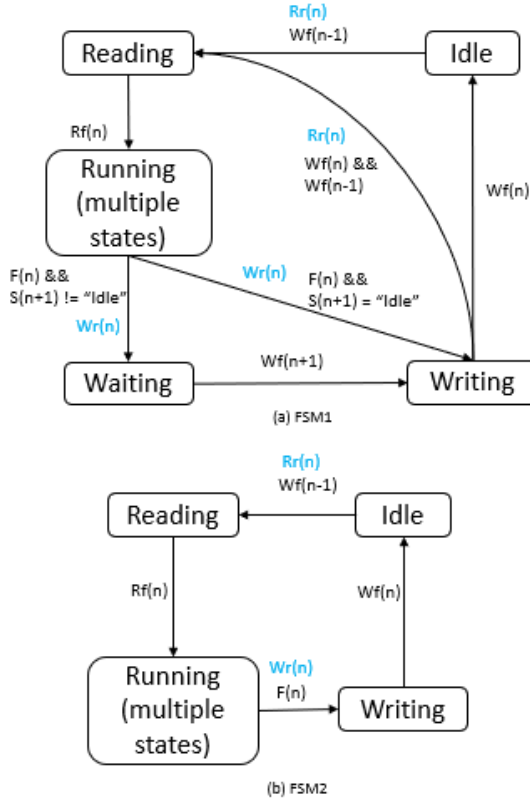
Figure 3. Two FSMs, namely (a) FSM1 and (b) FSM2, used according to our proposal. F indicates the task finishing signal sent from the respective processor. S indicates the state of the FSM of the respective processor. Inside the bracket, n indicates the processor the FSM corresponds to (current processor), and n-1 and n+1 indicate the last and next processors. Outputs with the respective edges are colored in blue. "&&" is logical "and" and "!=" is "not equal to".

Concurrent processor algorithms generate collective W_f signals, or W_f^c in case there are more than one last/next processors for a specific processor. We apply a counter in order to indicate the generation of the W_f^c for every case where the number of last/next processors is larger than 1. Starting from 0, the counted number is added by 1 every time an individual W_f is generated, and once it matches the quantity of last/next processors in the respective case, the W_f^c is generated, and then the number returns to 0. Take Figure 1 (a) for example, W_f^c should be generated for Task 1 as $W_f(n + 1)$ and for Task 4 as $W_f(n - 1)$. There is a counter for each of the cases, and both has their W_f^c generated when the number reaches 2.

The architecture should be able to take the advantage of simplicity in terms of data storage. According to Figure 3 (a), for example, since there are 5 major states for non-terminal processors, 3 bits of memory spared for every FSM of the first type is enough for the key part. For terminal processors, it will be 2 bits. As for the multiple states in the running part, since the operations are serial and non-stop, primary memory comes into consideration along with secondary memory. For example, if a byte of secondary memory is arranged for a non-terminal FSM, there will be 5 bits for the states in

running part. Then, primary memory will be used if the number of operations exceeds $2^5 = 32$. The number could also be less than 32 so that more primary memory is used to improve the speed.

As for data access, since the advantage of inter-processor data passages is the usage of a fixed memory space for every processor, the process of data passage can be largely automated, resulting in distributed architectures. Nonetheless, we need a memory supervisor to decide when to enable data passage between the memory spaces of two processors with dependency, regarding the W_r or R_r signals it receives. After the data passage is finished, the memory supervisor sends a W_f signal to the FSM of the writing processor and R_f signal to that of the reading processor. We can skip the issue of priority by applying an individual bus to every FSM for sending W_f signals.

We divide the conditions for data passages into two types: 1) uncrowded, which means when the writing processor gets its data ready, the FSM of the reading processor is at idle state, so the data passage can take place immediately; 2) crowded, which means when the writing processor gets its data ready, the reading processor is not at idle state, so the writing processor has to wait, and the data transition has to take place later. Because a processor stops reading new data and has its data stored in its memory space when its FSM is at waiting state, it owns only one set of data at one time, and the data will not stack up infinitely. And because the terminal processor(s) do not have waiting states, the non-terminal processors will not have its FSM at waiting state indefinitely either. In case the processors with their FSMs in waiting states stack up, and the enabled memory spaces form a chain in a TDG, we call it a waiting chain. This concept is potentially useful in improving the efficiency of the architecture, as when the end processor(s) in a waiting chain finished running tasks and writing data, the data passage on the chain can happen as quickly as possible. Thus, efficiency improvement schemes, such as using caches, can be investigated.

4. Test on Software

We tested the feasibility of our framework on software by modifying an open-source electrocardiogram (ECG) detection and classification program. [3] The objective of the test is to verify the availability of the proposed multiprocessing framework via the multithreading implementation, so maintained performances in accuracy and speed are primarily expected. If there are available resources in hardware such as thread executions being distributed to multiple cores, improved speed will also be expected.

The ECG program is written in C language, which is the same language to be used in our modification. The database it uses for performance evaluation is MIT-BIH database. [3][4] 25 ECG records are used in total, each of which has around 1000 to 3000 beats (QRS component) for detection and classification. Through code analysis, we divided the program into subtasks and determined their dependencies. Thus, they made up 6 modules as shown in the DAG of Figure 4, and their functionalities are shown in Table 1. Then, for multithreading implementation, we made use of the POSIX Threads model, or "pthread" header file. Every module was therefore fit into a thread. In code modification, we introduced a flag between every two individual threads where dependency exists. Writing and reading threads here correspond to writing and reading processors in our architecture. Collective flags, corresponding to collective W_f^c signals, are simply implemented by logical AND operators. For data

storage and access, we largely replaced variables by arrays, and arrays by double arrays, in order to store the buffering data to be used. Public data to be used by one thread were converted into private ones as an implementation of reading process. Similarly, private data were copied to public ones as a writing process. Proper mutual exclusion functions, such as "pthread_mutex_lock", were applied.
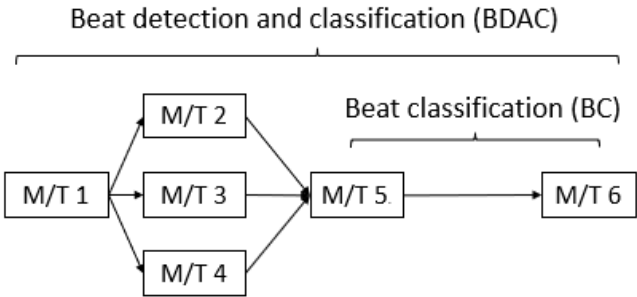
Figure 4. TDGs with our task segmentation method for testing. M/T represents module/thread.

Table 1. The functionality within every module

No. of module	Main functionality
1	Read sample, init, detect beat, etc.
2	Estimate noise
3	Downsample beat
4	Update beat queue
5	BC init, check muscle noise, check rhythm, analyze beat, etc.
6	BestMorphMatch (find the template that best matches the beat), update beat type, other BC tasks, other BDAC tasks, output beat type, etc.

We tested our modified program using GNU Compiler Collection (GCC) for compiling and compared it with the original program. The computer we used for testing is installed with the Intel i7-6700 CPU which has 4 cores, and Microsoft Windows 7 operating system. We tested the running time for every record using (1) the "clock" function via "time.h" header, and (2) a manual timer, according to when the start of execution of every record was printed. With the clock function method, the printed running time per record for the original program is around 500 – 1,000 ms, while for our multithreaded method it is around 90,000 – 120,000 ms. According to the manual timer, however, the running time per record is around 14 - 17 s for both programs. In terms of accuracy, we achieved "almost" the same performance in accuracy as the original program for the multithreaded program. Figure 5 shows some of the results to illustrate our observations. The results from manual timer method meet our expectations and are more convincing to us as the time measurement inside the program may be disrupted by pthread functions. As for the fact that no speed improvements are observed, as is understood, there are several obstacles in the effective time reduction for a multithreaded program such as the inability for user-level threads to save the running time, and the incompatibility between C language and multithreading functions as well as that between pthread functions and Windows OS.

Original Modified

Record 104

```
      n    v   f   q   o   x              n    v   f   q   o   x
N |  98    0   0   0   0   0      N |  98    0   0   0   0   0
V |   1    0   0   0   0   0      V |   1    0   0   0   0   0
F |   0    0   0   0   0   0      F |   0    0   0   0   0   0
Q | 1681 76   0   0   1   0      Q | 1704 53   0   0   1   0
O |   0    2   0   0              O |   0    2   0   0
X |   0    0   0   0              X |   0    0   0   0
```

QRS sensitivity: 99.95% (1856/1857) | QRS sensitivity: 99.95% (1856/1857)
QRS positive predictivity: 99.89% (1856/1858) | QRS positive predictivity: 99.89% (1856/1858)
VEB sensitivity: 0.00% (0/1) | VEB sensitivity: 0.00% (0/1)
VEB positive predictivity: 0.00% (0/2) | VEB positive predictivity: 0.00% (0/2)
VEB false positive rate: 0.112% (2/1781) | VEB false positive rate: 0.111% (2/1804)

Record 105

```
        n    v   f   q   o   x            n    v   f   q   o   x
N | 2100   19   0   0   0   0    N | 2101   18   0   0   2   0
V |   11   18   0   0   0   0    V |   11   18   0   0   0   0
F |    0    0   0   0   0   0    F |    0    0   0   0   0   0
Q |    5    0   0   0   0   0    Q |    5    0   0   0   0   0
O |   18   18   0   0            O |   18   18   0   0
X |    5    1   0   0            X |    5    1   0   0
```

QRS sensitivity: 99.91% (2153/2155) | QRS sensitivity: 99.91% (2153/2155)
QRS positive predictivity: 98.09% (2153/2195) | QRS positive predictivity: 98.09% (2153/2195)
VEB sensitivity: 62.07% (18/29) | VEB sensitivity: 62.07% (18/29)
VEB positive predictivity: 32.14% (18/56) | VEB positive predictivity: 32.73% (18/55)
VEB false positive rate: 1.754% (38/2166) | VEB false positive rate: 1.708% (37/2166)

Record 106

```
        n    v   f   q   o   x            n    v   f   q   o   x
N | 1234   1   0   0   1   0     N | 1234   1   0   0   1   0
V |    4 455   0   0   1   0     V |    4 455   0   0   1   0
F |    0   0   0   0   0   0     F |    0   0   0   0   0   0
Q |    0   0   0   0   0   0     Q |    0   0   0   0   0   0
O |    0   0   0   0             O |    0   0   0   0
X |    0   0   0   0             X |    0   0   0   0
```

QRS sensitivity: 99.88% (1694/1696) | QRS sensitivity: 99.88% (1694/1696)
QRS positive predictivity: 100.00% (1694/1694) | QRS positive predictivity: 100.00% (1694/1694)
VEB sensitivity: 98.91% (455/460) | VEB sensitivity: 98.91% (455/460)
VEB positive predictivity: 99.78% (455/456) | VEB positive predictivity: 99.78% (455/456)
VEB false positive rate: 0.081% (1/1235) | VEB false positive rate: 0.081% (1/1235)

Figure 5. Test results of our modified multithreaded program for three ECG records (Records 104, 105 and 106) in comparison with the original results. Lowercase letters are beat types through classification, while uppercase letters are real beat types.

5. Conclusion

We proposed a framework for multiprocessing adjustable for biomedical applications, and then an embedded system architecture with finite state machines and a data processing unit that handles memory access and storage for different processors. We verified the feasibility of the framework by implementing a respective multithreading scheme on an ECG detection and classification program on software. In the future, we aim at addressing other issues such as load balancing and real-time system

architectures. as well as investigating in more specific biomedical systems and modifying our proposals accordingly.

Acknowledgements

References

[1] Hussain T., Haider A., Taleb-Ahmed A., "A heterogeneous multi-core based biomedical application processing system and programming toolkit". Journal of Signal Processing Systems, vol. 91, no. 8, pp. 963-978, 2019.
[2] "Hardware Cost Design Optimization for Functional Safety-Critical Parallel Applications on Heterogeneous Distributed Embedded Systems"
[3] Hamilton P. (2002), "Open source ECG analysis," Computers in Cardiology, 2002, pp. 101-104, doi: 10.1109/CIC.2002.1166717.
[4] The MIT-BIH Arrhythmia Database CD-ROM. Available from the Harvard-MIT Division of Health Sciences and Technology, 1992.

A Comparative Study of Intercultural Communication in China and Japan

Fengyun ZHANG and Yan LI[1]

East China University of Science and Technology，China

Abstract. This paper presents the current situation of intercultural communication research in China and Japan in terms of the publications, theoretical constructs, the activities of the Institute and the configuration of intercultural communication courses. The purpose is to identify the strengths and weaknesses in comparison, and then to explore feasible approaches for the development of intercultural communication research in China. It is found that China can further promote the research in this field by increasing funding for theoretical research, introducing classic original works, involving professionals in translation and encouraging multidisciplinary and sustainable development.

Keywords. Intercultural communication studies, theoretical constructs, multidisciplinary, sustainable development

1. Introduction

Intercultural communication exists in every corner of human life. *The Silent Language*, written by Edward Hall in 1959, first used the concept of intercultural communication and made an in-depth analysis of verbal communication behaviour. It can be called the foundation work of intercultural communication. It is generally accepted that intercultural communication research began in Europe and the United States in the 1940s and 1950s. Since then, after six or seven decades of refinement and continuous exploration by many scholars, intercultural communication research has made significant progress and gradually become an independent discipline, as characterized by the publication of a large number of academic works, the convening of related academic conferences, the establishment of research and education societies, and the setting of university curricula, especially the theoretical framework is gradually clear and the content is constantly enriched. Intercultural studies in both China and Japan began after the United States had already achieved certain results. Japan was about 20 years ahead of China, starting with a large number of translations of European and American treatises on the subject and developing them as they were introduced, studying both other countries and their own, until they developed into a new period with a relatively complete system from popular science to theory. This paper will make a comparison from four aspects: the books written, the theories created, the activities of the Institute's research and the intercultural communication-related courses offered in universities.

---

[1] Corresponding Author, Yan LI, School of Foreign Languages, East China University of Science and Technology, Shanghai, China, 200237; E-mail: liyan@ecust.edu.cn.

2. Papers and Books on Intercultural Communication

The authors conducted a search on CiNii using the keyword "Intercultural Communication" and counted the number of papers from 1980 to 2020, as shown in Figure 1. As Ro Tao pointed out, Japan's research in this field experienced the exploration period in 1980s and the development period in 1990s [1]. However, at the same time, the rapid development in the early 21st century was also very evident until the momentum of development slightly weakened and gradually stabilised around 2013.
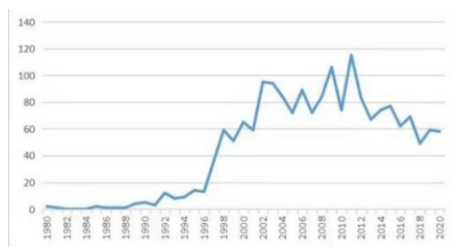
Figure 1 Statistical Table of IC Papers in CiNii, Japan

The authors counted a total of 98 articles in CiNii in 2017 and 2016, covering 26 articles on intercultural communication (including various aspects such as methods, basic concepts, behaviors, etc.); 22 articles on foreign language teaching, learning and research, and 17 articles on intercultural understanding, education and communication; 5 articles on intercultural adaptation (including nursing, training, parenting, etc.); 3 articles on identity; 7 articles on reports on overseas studies; 3 articles on foreign students' education; 3 articles on cultural comparison, and other contents such as diplomatic war, Japanese theory, etc. The following years also witness the multidisciplinary nature of research in this field. It is also interesting to note that from 2008 to 2020 Junko Aoki has been working on "'Fictional World' and 'Real World': Connecting the act of reading fiction with the act of learning intercultural communication". From fictional depictions of separation, death and reality given to children to homosexuality and even the two struggles of Hillary and Clinton, it is examined in a comprehensive manner in a series of discourses.

In terms of books, a number of scholars, such as Satoshi Ishii and Richiko Ikeda, have worked for many years to produce a complete system of books in this field in Japan, ranging from introductory books with the nature of popular science, the development of research methods, the study of practical training activities to the construction of a theoretical system. For example, the book *Intercultural Communication: The New Intercultural Conditions* covers the basic concepts of communication and also intercultural communication education, etc. [2] The book *Intercultural Communication Research Methods* introduces the general research methods of intercultural communication, each chapter accompanied by citations and references to facilitate extended study and research [3]. In the book *Introduction to Intercultural Communication*, whether it is the explanation of concepts or the dynamics of intercultural contact in specific scenes, it is limited to two pages, which are full of content [4]. The book cites classics, reviews and prospects, and has rich connotations. In addition, there is *The History and Present of Intercultural Contact*, which examines the history and present of intercultural contact from a historical perspective

[5]; *Theories of Intercultural Communication*, which critically interprets existing theories related to intercultural communication[6]; and *Intercultural Understanding and Communication 1&2*, which deals with communication from various perspective, is divided into two volumes: *Language and Culture*[7]*;* and *People and Organisations*[8]*.*

In the research, the authors found that a large number of foreign original works and translations in this field were published in Japan. Just take the book *Introduction to Intercultural Communication* as a popular science academic works that advocates self-learning, self-thinking, and independent creation of (knowledge) systems, for example, the text is annotated with a bibliography of books referenced by the editors, including 48 original titles and 104 translations (translations involving nearly 100 scholars and 42 publishers). This has contributed to the simultaneous development of intercultural communication research in various fields.

In order to clarify the current situation of this field in China, the authors searched CSSCI papers from 1989 to 2020 on Wanfang Data Knowledge Service Platform with "intercultural communication" as the key word, and the statistical results of the number of papers are shown in Figure 2. In the 21st century, China has successively hosted the Beijing Olympic Games, the World Expo and the G20 Summit, and the "Chinese element" has gained a remarkable status in the international arena. At the same time, investment in scientific research has increased significantly and the number of papers in various disciplines has soared, benefiting intercultural communication research as well. It can be said that intercultural communication research in China was in its infancy in the 1980s and 1990s, and has since rapidly entered a period of rapid development, with the year 2000 as the boundary, and has shown a marked decline in recent years.
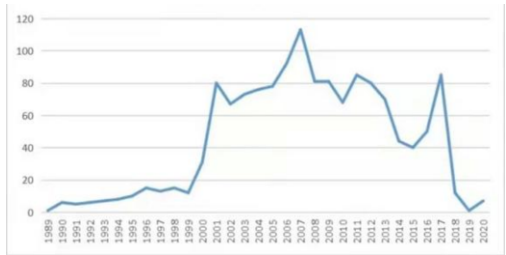
Figure 2 Statistical Table of CSSCI IC Papers on Wanfang Data Knowledge Service Platform, China

In terms of books, there are many classic works, such as *Intercultural Communication Research*, which can be called a guide to communication with British and American people, closely follows foreign research results [9]. Besides, there is *Intercultural Communication Studies*, which interprets the concept of intercultural communicative competence from a multidisciplinary perspective and discusses it through facts and figures [10]; *An Introduction to Intercultural Communication Studies*, which is an introductory guide in this field [11]; and *Intercultural Communication Theory*, which systematically reviews the classical theories of today, taking the core issues of intercultural communication as a framework [12]. In general, however, the books with the title "intercultural communication" are mostly textbooks for university general education, foreign language education and Chinese as a foreign language education. Searching the English version of books, there are *Communication Between*

Cultures [13] and the photocopied and adapted version of *CROSS-CULTURAL COMMUNICATION* (8th edition) [14], but the number is extremely limited.

Despite the rapid development of theses and books, the problems that have existed over the years have not yet been resolved. Hu Wenzhong, when counting some of the books and collections of papers published in China from the mid-1980s to the mid-1990s, pointed out that the research at that time focused on "1) the relationship with verbal communication; 2) non-verbal communication; 3) comparison of Chinese and Western customs; 4) comparison of Chinese and Western business management modes; and 5) studies on nationality. There has also been some discussion of the theories and research methods of intercultural communication studies, but, in general, there have been fewer works in this field [15]."

However, the development in the next decade is still not optimistic. Peng Shiyong discussed the current situation of intercultural communication research in China by analyzing the contents of 1,109 papers on intercultural communication published in 564 domestic academic journals from 1994 to 2003, and pointed out the main problems: poor theoretical research, narrow research scope, many articles of "shallow discussion", "tentative discussion" and "brief discussion", and few empirical research results [16]. To solve these problems, we must promote and encourage the use of scientific research methods for intercultural communication research.

Then, from the research of Liao Caizhi, it is found that after more than 30 years of intercultural communication research, the problem was the same as ever [17]. Taking "intercultural studies" as the key word, he counted and analyzed 3,854 papers on intercultural communication collected from January 1, 2002 to January 1, 2012, published by 500 domestic journals, conference papers and newspapers and included in China Academic Journal Network Publishing General Database, China Academic Journal Full-text Database, China Important Conference Papers Full-text Database and China Important Newspapers Full-text Database, etc. The problems found are as follows: the research in various fields is extremely unbalanced, the research scope is narrow, the inherent thinking mode is partial, the theoretical research is relatively poor, and scientific research methods are lacking.

3. The Construction of Intercultural Communication Theory

Pei Bei divides the study of intercultural communication theory into three stages in terms of chronology, namely, the early research, the 1960s-1980s and the 1980s-present [18]. On this basis, this paper presents the theoretical construction of China and Japan in these stages respectively. In terms of theoretical construction, the United States has always been at the forefront of intercultural communication research. Early research can be traced back to the post-World War II to the mid-1950s, in order to adapt foreigners to American culture, cultivate pro-American groups and conduct cross-cultural training for American diplomats and people who are going to work overseas. At this time, theoretical research on intercultural communication was mainly a comparative study of differences between different cultures. The most representative are American anthropologist Hall's cultural behavior composition and high and low context culture theory, Kuluckhohn&Stordtbeck's cultural value orientation theory and Hofstede's theory of cultural dimensions. By this time, the Japanese scholar Tetsuro Watsuji had denied the 'individualism' of Western philosophy and proposed the concept of 'interpersonalism', which focuses on the relationship between human beings

[19], which laid the foundation for the contextualism put forward by Eshun Hamaguchi [20]. The theoretical construction of this period in China has not yet begun.

From the 1960s to the 1980s, the United States began to study the many problems that young people who participated in the Vietnam War and peacekeeping forces displayed during their exposure to overseas cultures and their readjustment to their own cultures after returning home, followed by practical training in mainstream cultural adaptation and intercultural adaptation for international students, international business people, immigrants and others, and began to experiment with theoretical research. On the basis of early research results scholars put forward a series of related theories centred on cultural adaptation, including the intercultural adaptation cycle theory, which uses the communicator's psychological and emotional factors as a basis for measurement and provides a one-way, linear depiction of the adaptation process (e.g. Lysgarg's U-curve model, Gullahorn et al.'s W-curve model, Junaman's six-stage theory of intercultural adaptation, etc.); from the macro level, it reveals Berry's intercultural adaptation strategy of diversity and multidimensional cultural adaptation process and Kim&Ruben's comprehensive and three-dimensional intercultural adjustment theory by putting forward a "third culture". The theoretical construction of this aspect lags behind slightly in Japan, which developed its own theory on the basis of studying European and American theories. For example, Yoshiyasu Uno defined Everett M. Roger's "re-invention" as "transcultural refraction" [21]; Hirobumi Sakaki developed the concept of "Pre-refraction" [22].

After the 1980s, the whole academic circle began to focus the core issues of intercultural communication theory on a certain level of communicative process such as identity, meaning and competence. For example, Cupach & Imahori understand identity as an interpretative framework with an empirical dimension, where identity provides expectations and motivations for individual behaviour, and any individual has multiple identities, but their cultural and relational identities are central to identity management. When discussing identity interaction, it focuses on analyzing the face behavior of communicative individuals, and holds that the behavior of maintaining face is the concrete behavior of identity management. Ting-Toomey proposed a theoretical model of face-negotiation linking cultural differences with conflict management strategies around the issue of identity conflicts in intercultural communication [23]. Milton J. Bennett created a model for the development of intercultural communicative sensitivity that focuses on national superiority (the predominance of one's own cultural worldview) and national relativism (accepting many standards and customs and consciously adjusting behaviour and judgement standards in intercultural situations) [24, 25]. Darla K. Deardorff advocated the pyramid model[3] of intercultural adaptability including internal and external results. Chinese and Japanese scholars have also made a breakthrough in their research on "identity" and "competence" [26]. Japanese scholar Eshun Hamaguchi's contextualism, under the influence of Ruth Benedict's extreme dichotomy of collectivism and individualism, focuses on the relationship between people, introduces the perspective of "the relatum" and redefines the definition of "collective" as "the sum of relational entities" [19].

Chinese scholars have also made many attempts in the theoretical construction of intercultural communicative competence, and have developed a number of ideas and theories of reference value. Lin Dajian explains the three dimensions of intercultural communicative competence: 'behaviour, knowledge structure and moral ethics' [27]; Gao Yihong uses "Tao and Instrument" to interpret the connotation of intercultural communicative competence [28]; Xu Lisheng identifies our dimensions of intercultural

communicative competence: grammar, social language, discourse and strategy [29]. Chen Guoming thinks that communicative competence is similar to intercultural communicative competence. The only difference is that intercultural communicative competence emphasizes contextual context. Besides the effectiveness and appropriateness of interpersonal interaction, it also pays great attention to the interaction between people and the communicative environment and the cultural identity of both parties [30]. In addition, there are Gao Yongchen's moderate principle of cultural empathy and the intercultural communication evaluation system including knowledge system and performance system [31]. The above-mentioned scholars have either focused on the principles of linguistic rules or refined their own culture to explain the connotations of intercultural communication, which has contributed to the theoretical research in this field in China.

Besides, the research results of Chinese and Japanese scholars on their own culture and their own people are also very remarkable, such as Chie Nakane's *Japanese Society: A Practical Guide to Understanding the Japanese Mindset & Culture* which emphasizes the particularity of the Japanese[32]; Takeo Doi's *The Anatomy of Dependence*[33]*,* Takeo Funabiki's *Reconsideration of Theories of Japanese Culture*[34]; Jia Yuxin's "The Concept of Harmony and Difference", which emphasizes the characteristics of Chinese culture[10]; Chen Guoming's "Harmony" concept in Chinese interpersonal communication[35]; Hu Chao's "Oneness with the Universe", which is the core of the structure of intercultural communication[36]. They have played a positive role in promoting the development of intercultural communication research in both countries.

4. Other Aspects Related to Intercultural Communication Studies

When it comes to intercultural communication research, the authors believe it is necessary to examine the resources that have contributed and facilitated the research.
In Japan, the "Intercultural Communication Society" (SIETAR JAPAN for short) is quite influential. Founded in 1985, the Society is a branch of SIETAR International, which was founded in 1974. The society is mainly engaged in activities, research and practice, and cultivates smooth communication and cooperation between people and organizations of different cultural backgrounds. The Society holds monthly regular meetings and annual general meetings, and also edits and publishes the Society's minutes and the journal *Intercultural Communication*. In addition, the Institute of Intercultural Studies of Kanda University of International Studies, which is affiliated to the Kandagaigo Group, was established in 1983. From language, religion to economy, politics and education, the Institute edits and distributes the journal *Intercultural Communication Studies* for the purpose of engaging in various related research, education and enlightenment activities in this field. It was later merged with the University's Institute of International Studies in 2012 into the Institute of Global and Intercultural Studies. In addition, there are many resources available in Japan to facilitate research, namely, encyclopedia, websites and corpora and so on, such as 10 volumes *World Encyclopedia of Events* [37]; *Communication* (MSN Encarta Encyclopedia) [38]; *Multicultural Understanding Dictionary* [39]; *Heterocultural House* [40], etc.

In China, the first Intercultural Communication Symposium was held at Harbin Institute of Technology in 1995 and China Association for Intercultural Communication,

a national non-governmental academic organization affiliated to the Foreign Language Teaching and Research Branch of Chinese Higher Education Society, was established to hold a national/international academic symposium every two years. From 2016 onwards, the Association convenes a small high-end forum in every even-numbered year and a large international conference in every odd-numbered year. The Association edits and publishes the Journal of *Intercultural Studies Forum* [41]. Universities in China have established research institutes related to intercultural communication, such as the Institute of Intercultural Communication at Zhejiang University, now called the Institute of Intercultural and Regional Studies, which was formally established in 2004. In addition, as China's "Chinese culture going global" and "One Belt, One Road" communication is in demand, various associations and research institutions are actively building platforms to strengthen China's international communication capacity and accelerate the construction of Chinese discourse and narrative system. These initiatives have contributed to the study of intercultural communication in China, but the aims and activities of these research institutions mentioned above show that they are mostly in areas where foreign language teachers are active and lack diversity. Within the scope of the authors' investigation, the current research tends to be empirical and no significant results have been seen in the construction of theory in this field.

In terms of curriculum, this paper draws lessons from the research results of Li Mingling et. al and makes a comparison between China and Japan. They used the keyword "Syllabus Intercultural Communication" in Yahoo Japan and input "Specified for a period of up to one year" to target the top 10 schools. The course is offered by departments such as Business Administration, Humanities, Education, Culture, Arts and Sciences, and Japanese Language Education and Research, and is mostly taught over two semesters at four credits. The aim of the course is to acquire the theory of intercultural communication, improve intercultural communication skills, and evaluate one's own abilities through experience, grasp, analysis and comparison. The language requirements for teaching focus on Japanese and English. It's characteristic that there can be international students among those who choose courses. The teaching content varies considerably between universities and is highly variable. The teaching methods are mostly discussions, training, presentations and group discussions. At the same time, they also made an investigation on the courses whose syllabus has been published on "China National Excellent Course Resource Network". It was noted that in 10 universities, nine of the courses were offered in the College of Foreign Languages and one in the College of International Education. The content of the course was mainly lectures, with a relatively small proportion of discussions, case studies and group activities. In addition, the course suffers from a lack of home-made domestic textbooks, a short start period, unclear objective setting, single teaching method, and a lack of experience of the lecturers [42]. The authors conducted a survey on issues related to the course "Intercultural Communication" for undergraduate Japanese language students in domestic universities through Questionnaire Star in October 2019, and found that the above deficiencies still exist [43]. They will certainly lead to limited breadth and depth of research in related fields, and even if entry points are found in teaching practice, the lack of a background of multidisciplinary and comprehensive class knowledge often leads to superficial research.

5. Conclusion

The study found that the quality of domestic intercultural communication research is still uneven, the number of original books and translations is obviously insufficient, researchers are specialized in a single field, and there are few theories with both international influence and Chinese characteristics. It is possible to promote intercultural communication research in China by increasing funding for theoretical research on intercultural communication; introducing classic original works; encouraging professionals in the field of sociology to participate in the translation of original works; strengthening the training of foreign language teachers and interdisciplinary development of Chinese as a foreign language teachers through societies or institutes; and adhering to sustainable development and other aspects.

References

[1]   Ro. T. History and Current Status of Intercultural Communication Research in Japan. Hiroshima University, Management Studies; 2007: 79-92.
[2]   Ishii S., Okabe R., Kume A. Intercultural Communication: The New Intercultural Conditions. Yuhikaku Press; 1996.
[3]   Ishii S., Kume A. Intercultural Communication Research Methods. Yuhikaku Press; 2005.
[4]   Ikeda R. Introduction to Intercultural Communication. Minerva Press; 2012.
[5]   Hosoya M. The History and Present of Intercultural Contact. Sekaishisosha; 2006.
[6]   Ishii S., Kume A., Toyama A. Theories of Intercultural Communication. Yuhikaku Press; 2001.
[7]   Honnna N., Bates H., Akiyama K., Takeshita Y. Intercultural Understanding and Communication 1: Language and Culture. SANSHUSHA; 2005.
[8]   Honnna N., Takeshita Y., Brook H., Akiyama K., Bates B. Intercultural Understanding and Communication 2: People and Organisations. SANSHUSHA; 2005.
[9]   Lin D. J. Intercultural Communication Research. Fujian People's Publishing House; 1996.
[10] Jia Y. X. Intercultural Communication Studies. Shanghai Foreign Language Education Press; 1997.
[11] Hu W. Z. An Introduction to Intercultural Communication Studies. Foreign Language Teaching and Research Press; 1999.
[12] Dai X. D. Intercultural Communication Theory.Shanghai Foreign Language Education Press.2011
[13] Larry A. Samovar et al., Communication Between Cultures. Foreign Language Teaching and Research Press; 2007.
[14] Larry A. Samovar et al., CROSS-CULTURAL COMMUNICATION (8th edition) (translated by Dong X. B.). Peking University Press; 2017.
[15] Hu. W. Z. Introduction to Intercultural Communication. Foreign Language Teaching and Research Press; 2004.
[16] Peng. S. Y. Current Situation, Problems and Suggestions of Cross-cultural Communication Research in China. Journal of Hunan University (Social Science Edition); 2005, No.19 (3): 86-91
[17] Liao. C. Z. Analysis of the Current Situation of Cross-cultural Communication Research in China in the Past 10 years. Southeast Communication; 2012(11): 15-18
[18] Pei. B. Research on Intercultural Communication Theory and Research Trends. Journal of Chinese Language Teaching, General Series 12; 2020:133-150+155
[19] Yuasa Y. Human and Ideology. San-ichi Shobo; 1973.
[20] Hamaguchi E. What is Japanese Society: From the Perspective of "Complex_System". NHK Books; 1998.
[21] Uno Y., et al., The Mechanism of International Conflict: With special reference to Transcultural Refraction Hypothesis. SAIENSU-SHA; 1983.
[22] Sakaki H. Cross Cultural Business Strategy: From the Perspective of Pre-refraction. DOBUNKAN; 1994.
[23] Gudykunst, W. B., & Ting-Toomey, S. Culture and Effective Communication. American Behavioral Scientist; 1988: 31(3), 384‑400.
[24] Bennett. M. J. A developmental Approach to Training for Intercultural Sensitivity. International Journal of Intercultural Relations; 1986:10 (2), 179-196.

[25] Bennett M. J. Intercultural Sensitivity. Principles of Training and Development. Portland State University; 1993:25(21), 85-206.

[26] Deardorff D. K. Identification and Assessment of Intercultural Competence as a Student Outcome of Internationalization. Journal of Studies in International Education; 2006:241-265.

[27] Lin D. J. Intercultural Communication Studies. Fujian People's Publishing House; 1996

[28] Gao Y. H. Tao and Instrument of intercultural communicative competence. Language Teaching and Linguistic Studies; 1998(3): 39-53

[29] Xu L. S. Communicative competence and intercultural communication. Journal of Zhejing University (Humanities and Social Sciences); 1997 (3):105-110

[30] Chen G. M. Foundations of Intercultural Communication. East China Normal University Press; 2009.

[31] Gao Y. C. Moderate Principle of Cultural Empathy in Intercultural Communication. Foreign Languages and Their Teaching; 2003(8): 29-34.

[32] Nakane C. Japanese Society: A Practical Guide To Understanding The Japanese Mindset&Culture. Kodansha; 1967.

[33] Doi T. The Anatomy of Dependence. Kodansha; 1971.

[34] Funabiki T. Reconsideration of Theories of Japanese Culture. Kodansha; 2002.

[35] Chen G.M. Toward transcultural Understanding: A harmony theory of Chinese communication. In V. H. Milhouse, M. K. Asante, and P. O. Nwosu (Eds.), Transcultural realities: Interdisciplinary perspectives on cross-cultural relations; 2001：55-70

[36] Hu C. The Attainment of Oneness with the Universe and Intercultural Communication. Foreign Languages and Their Teching; 2001(12): 53-55.

[37] World Encyclopedia of Events, Heibonsha; 2007.

[38] http://jp.encarta.msn.com/ encyclopedia_761564117/content.html

[39] http://www.netlaputa.ne.jp/ ~ Tokyo 3/

[40] http://www.geocities.jp/ibunkaya/index.html

[41] http://chinacafic.heep.cn

[42] Li. M. L. and Makihara. I . A Comparative Study of Intercultural Communication Courses in China and Japan---Through Syllabus. Edited by Center for International Education and Research, Gunma University; 2014(13): 15-26

[43] Zhang. F. Y. A study on the Current Situation of Intercultural Communication Course for Undergraduate Japanese Majors in Chinese Universities. West Japan Education Research. West Japan Education Research Association; 2020: 58-68

Research on Comprehensive Reform of Education Mode of Computer Specialty in Colleges and Universities in the New Engineering Era

Jun WANG, Dongxu LUO, Jiying MA[1]

College of Computer Science and Technology, Shenyang University of Chemical Technology, Shenyang 110142, China.

Abstract. The construction of new engineering is an important part of higher education reform in the new era. The construction of new engineering will accelerate China's transformation from a big country of engineering education to a powerful country of engineering education. Therefore, this paper puts forward a "new model" of talent training in engineering education. In the process of building first-class computer majors, taking engineering certification as an opportunity to promote the construction of first-class computer majors, taking the practice base as the tentacle, and creating a practice system under the real scene, through the "Trinity" talent training mode, from talent training scheme design to curriculum system construction, from teacher team construction to first-class curriculum construction, from student training to ideological and political construction, it has opened the deep integration of industry, University and research A good mechanism for collaborative education, so as to improve students' abilities in all aspects.

Keywords. New engineering construction, educational mode of computer specialty, engineering education, collaborative education

1. Introduction

The professional training goal is the wind vane of teaching behavior, with the development of higher education and the adjustment, transformation and upgrading of industrial structure, the professional training goal should focus on the needs of regional development and industrial development, and cultivate students with good cultural literacy, professional ethics, legal spirit, innovative thinking and other basic qualities, and application-oriented talents with basic professional knowledge and professional skills. In recent years, more and more new models of talent training have been proposed in different disciplines [1-3], the application of the teaching model based on engineering education accreditation [4] of thinking cultivation has been applied in various fields [5-6], it is imperative to reform the teaching mode of computer major in colleges and universities. Therefore, this paper puts forward a "new model" of talent training in engineering education. From talent training scheme design to curriculum system construction, from teacher team construction to first-class curriculum construction,

---

[1] Corresponding Author, Jiying Ma, College of Computer Science and Technology, Shenyang University of Chemical Technology, Shenyang 110142, China; E-mail: 382134224@qq.com.

from student training to ideological and political construction, a complete set of practical education and teaching mode has been established.

2.   New mode of computer specialty construction

2.1   Taking engineering certification as an opportunity to promote the construction of first-class computer majors

2.1.1   Identify training objectives and standardize teaching management.

Aiming at the demand of market development for talents, combined with the format of contemporary IT industry, computer science and technology disciplines are preliminarily divided into big data, artificial intelligence, software development and Internet of things. The professional training goal is the wind vane of teaching behavior. With the development of higher education and the adjustment, transformation and upgrading of industrial structure, the professional training goal should focus on the needs of regional development and industrial development, and cultivate students with good cultural literacy, professional ethics, legal spirit, innovative thinking and other basic qualities, and application-oriented talents with basic professional knowledge and professional skills. When formulating training objectives, full investigation and regular feedback mechanism shall be carried out to determine the rationality of training objectives and continuously improve them.

2.1.2   Optimize the curriculum system and improve teaching efficiency

According to the CDIO mode, the specialty constructs an integrated curriculum system that meets the output requirements in combination with the characteristics of the University and the specialty of planning. Starting from cultivating students with a solid professional theoretical foundation, good humanities and social science literacy and professional ethics, and the ability to solve complex engineering problems, the teaching links composed of courses, projects, internships, practices and various extracurricular activities integrate knowledge Ability and quality are coordinated and integrated in a way of mutual connection and support, so as to realize the goal of professional training in an integrated way. Clarify the contribution of each course or link in the curriculum system to the professional training standard, that is, the curriculum system support matrix. The assessment method is designed according to the learning objectives, learning methods and feedback requirements, and the evaluation feedback and continuous improvement are carried out based on the training objectives. Meanwhile, according to the requirements of the national undergraduate education reform and new engineering construction in the new era, the knowledge of artificial intelligence, big data and Internet plus has been integrated into the specialized course teaching.

2.1.3   Strengthen CDIO Engineering Education Concept and build a three-level iterative project practice teaching system

A project runs through the four-year practical teaching mode of the University, and the project knowledge points cover the theoretical content of professional core courses. With

the deepening of professional courses, iterative development of the project is carried out to exercise students' project practical ability. From in class experiments, curriculum design, secondary projects, primary projects to graduation design and other practical teaching links, strive to cultivate applied talents with strong engineering practice ability required by the industry.

2.2 Take the practice base as the tentacle to create a practice system under the real scene.

According to the feedback of market information, timely revise the content of base practice projects, and complete the development of new technology fields in the market according to the design of base practice projects; The base project is linked with students' learning. According to the needs of the base project, several realizable, evaluable and teachable sub projects are set to link with students' daily learning, so that students can realize the project needs with the learned content. At the same time, students also propose innovative projects according to the learning results and incubate them in the base.

2.2.1 Strengthen the leading role of the experimental teaching center in the school and create a practical teaching platform

The experimental teaching center should build a provincial practical teaching platform with the construction concept of "one foundation and three strengthening". According to the CDIO Engineering Education Concept and the needs of computer engineering education experiment practice, the experimental teaching center, based on the cloud platform, strengthens resource integration, strengthens the construction of teaching system, strengthens school enterprise cooperation, and establishes experimental teaching platforms such as big data, artificial intelligence and Internet of things. The experimental teaching center should build a provincial practical teaching platform with the construction concept of "strong concept, foundation and comprehensive". The experimental teaching center strengthens the CDIO Engineering Education Concept, establishes a four-level basic experimental teaching system platform, and integrates complex problems to design comprehensive experiments.

2.2.2 Build an off campus practice base and create a "Trinity" practice system

Strengthen the cooperation between schools and enterprises and the construction of teaching base, and formulate a detailed construction and management system of industry university research practical teaching base. In order to realize the long-term cooperation mechanism of benign interaction between schools and enterprises, achieve the three goals of cultivating talents in market demand, enhancing students' practical ability and exploring the education mode of combining industry with education, the two sides reached a consensus to jointly carry out research on industry university research projects and build an off campus practical teaching base, so as to provide students with a perfect off campus practical learning environment. In the construction of off campus practice base, it is necessary to establish the "Trinity" construction mode of students, base and market, link the market information with the base project, and link the base project with students' learning, timely revise the content of the base practice project according to the feedback of market information, and complete the development of new technology fields in the market according to the base practice project design; The base project is linked

with students' learning. According to the needs of the base project, several realizable, evaluable and teachable sub projects are set to link with students' daily learning, so that students can realize the project needs with the learned content. At the same time, students also propose innovative projects according to the learning results and incubate them in the base.

3.   Collaborative education mechanism of industry education integration under the background of new engineering

The integration of industry and education and collaborative education is an important link in the talent training of "new engineering". The opinions of the general office of the State Council on deepening the integration of industry and education emphasize: "The main goal of deepening the integration of industry and education is to gradually improve the participation of industrial enterprises in running schools, improve the diversified school running system, fully implement the collaborative education between schools and enterprises, fully mobilize the enthusiasm and initiative of enterprises to participate in the integration of industry and education, strengthen policy guidance, and build a long-term mechanism for school enterprise cooperation." No matter in terms of talent training objectives, scope of cooperation and degree of integration.

3.1 School enterprise linkage

Employ experienced technical and management personnel of the enterprise as part-time teachers to give lectures in the school. On the other hand, teachers of this major are encouraged to practice in enterprises regularly to improve teachers' practical teaching ability and build a "double qualified" team of teachers. At the same time, actively explore the talent training mode of 3 + 1 school enterprise cooperation. In the first three years, students completed public basic, professional basic and professional technical courses in the school. In the fourth year, they went to the enterprise for engineering practice study, and completed the graduation design in combination with enterprise projects, so as to realize the seamless connection between talent training and enterprise needs, and also provide personalized services for students' academic growth, Achieve accurate and optimized collaborative teaching and training process.

3.2 Normalization of Ideological and Political Education

Ideological and political education can make college students always maintain good spirit and character, arm their thoughts with firm and conscious, and improve the party and the state's high recognition of principles and policies, so as to cultivate talents who meet the needs of the party and the state.

In the process of first-class professional construction, we should always normalize the ideological and political work, carry out curriculum ideological and political construction among teachers, strengthen the ideological and political concept among students, and integrate the ideological and political concept into the daily work and learning of each teacher and student. Establish the educational concept of "moral education first". Teachers should bring ideological and moral education into classroom teaching and infiltrate ideological and political education into classroom teaching.

Teachers' professionalism requires them to adhere to correct ideological and moral concepts, develop good professional ethics and ethics, and internalize them into their own behavior. Teachers can guide students to improve their ideas, and comb out the correct outlook on life and world outlook in the process of learning professional knowledge.

3.3 Guided by market demand, strengthen the awareness of innovation and entrepreneurship

Through the practice of the "Trinity" talent training mode, students can improve their working ability in project practice, shape the overall view of software development, exercise their communication ability, understand the theoretical and technological frontier and development trends, and strengthen the opportunity to integrate with the cutting-edge advanced technology. Attract outstanding students to participate in scientific research and innovation and create conditions for students to continue their further study through provincial practice centers, collaborative innovation platforms and other on campus and off campus cooperation bases. Through the construction of off campus practice base and employment base, help students understand their work ability and suitable work in multiple dimensions, and improve students' high-level employment rate through accurate recommendation.

4.   "Trinity" talent training mode

Under the "Trinity" talent training mode, the OBE education concept is adopted, and the training objectives are found in time and the teaching management is standardized according to the engineering certification and CDIO education mode. Optimize the curriculum system and improve teaching efficiency. Strengthen team building, improve teaching quality, improve teachers' comprehensive ability, and comprehensively improve the quality of talent training.

- Pay attention to personality and moral education to ensure the all-round development of students. The fundamental task of the school is to cultivate morality and cultivate people. In addition to the cultivation of professional ability, the school also places special emphasis on the cultivation of students' Ideological and moral quality, sense of social responsibility, innovation ability, personal professional ability, communication expression and team cooperation ability, which reflects the greatest love of the school for students' development.

- Implement integrated talent training to realize the synchronous improvement of students' knowledge, ability and quality. An integrated talent training program integrating professional education, innovation and entrepreneurship education and quality education has been implemented. According to the technology and process of real production and service, the structure, content and order of professional curriculum system have been redesigned, and an integrated curriculum system with ability orientation, five-level project traction and dynamic updating of content has been constructed to realize the integration of professional education and quality education, The integration of theoretical courses and practical courses, the integration of teaching, learning and doing,

the integration of in class teaching and extracurricular activities, the integration of school enterprise cooperation and vocational ability training.

- People oriented, teaching students according to their aptitude and implementing flexible teaching. The school pays attention to students' different characteristics and personality differences, and implements the credit system teaching management mode, as well as hierarchical teaching methods such as English Classification and mathematics classification; Through the construction of "4A" (anytime, anywhere, anytime, anywhere) flexible teaching system, explore the diversification of teaching locations, the combination of teacher arrangement, the normalization of project implementation, the mixing of learning methods and the diversification of assessment and evaluation, so as to provide more opportunities for students' learning and development.

5.   Conclusions

In the construction of first-class computer majors, through the "Trinity" talent training mode, from talent training scheme design to curriculum system construction, from teacher team construction to first-class curriculum construction, and from student training to ideological and political construction, a good mechanism of in-depth integration of industry, University and research and collaborative education has been opened. Explore the cultivation of students under the mechanism of industry education integration. Through the "Trinity" linkage mechanism, students can connect with the market during school, and then improve their ideological and moral quality, social responsibility, innovation ability, personal professional ability, communication and team cooperation ability.

Acknowledgments

References

[1]   S.S. Li, J.Y. G. Thoughts and Exploration on the reform of Ideological and political teaching in Colleges and universities of traditional Chinese medicine in the new era. Lishizhen Medicine and Materia Medica Research. 2019;30(11): 2741-2743.
[2]   Y. Ying, Y. Mei. Thoughts on the construction of new agricultural science in higher agricultural education. Journal of Zhejiang a& f University. 2019;36(1): 1-6.
[3]   W. Li. Performing the national teaching quality standards for undergraduates, comprehensively improving the training quality of Water Science and Engineering professionals. Water & Wastewater Engineering. 2020;46(7): 172-176.
[4]   H. Jiang. Construction and reform of water conservancy undergraduate majors facing new water conservancy situations in new era: thoughts based on engineering education accreditation. Advances in Science and Technology of Water Resources. 2021;41(1): 1.
[5]   W. Pan, Y. Feng, X. Zhang. Exploration and research on online teaching mode of Medical Immunology experiment course. Chinese Journal of Immunology. 2020;36(19): 2353-2356.
[6]   X. Sun, G. Zhu, J. Chen, et al. The application of the teaching model of thinking cultivation in microbiology teaching. Journal of Biology. 2019;36(5): 121.

Collaborative Control of Multi-Region Urban Traffic Boundary Based on the MFD

Yonghong XU[1]

Gansu Police Vocational College, China

Abstract. The increasing number of urban motor vehicle travel has brought more and more serious urban road traffic congestion in single region predicament. In order to study the traffic control problem of single-region urban network, a macroscopic model of traffic flow in urban region was constructed based on the macroscopic basic graph (MFD) theory to predict the traffic congestion pattern in urban region. In order to better explore the dynamic boundary control points, the queuing overflow of boundary sections was analyzed, and the regional boundary control strategy of real-time flow and queuing dynamics was given according to the real-time boundary morphology. In the case of improving and adjusting the signal timing of the input traffic flow at the boundary intersection, the regional traffic flow can be developed in a favorable direction, thus reducing the probability of overflow problems in the boundary section of the region, and contributing to the improvement of the overall operation efficiency of the region.

Keywords. MFD, congestion, multi-regional urban transport, control

1. Introduction

Macroscopic Fundamental Diagram (MFD) theory as a macroscopic modeling method for traffic flow on urban road networks is more suitable for developing traffic area control strategies and achieving optimal traffic flow efficiency on road networks[1]. Boundary control strategies based on MFD theory are one of the effective ways to deal with the regional traffic saturation or oversaturation dilemma. The control mechanism is to maintain the regional cumulative volume near the expected critical point by determining the boundary input flow to ensure the maximum volume of traffic within the region [2].

The boundary control strategy based on MFD is one of the effective means to solve the problem of regional traffic saturation or oversaturation. The main idea is to control the boundary input flow, maintain the regional accumulation near the desired key points, and achieve the maximum of regional traffic volume. In this paper, a MFD based dynamic boundary control strategy for single-region urban road network is proposed, in order to better solve the problems of signal control and road overflow at boundary intersections on the basis of improving the traffic operation capacity within the region.

In this paper, a MFD based dynamic boundary control strategy for single-region urban road network is proposed, in order to better solve the problems of signal

---

[1] Corresponding Author: Yonghong XU; Associate professor of Road Traffic Management, Department of Public Security, Gansu Police Vocational College; main research direction -- road traffic accident handling, traffic laws and regulations, etc.
 E-mail: xuyonghong202205@163.com

control and road overflow at boundary intersections on the basis of improving the traffic operation capacity within the region. In the second part, the relevant model is constructed. In the third part, kalman filter method is used to realize the dynamic test of queuing length. In the fourth part, the simulation experiment and analysis of urban road traffic in a city of China are carried out, and the signal control improvement strategy of dynamic boundary intersection is given.

2. Construction of macro-model of regional traffic flow

Assume that there are two parts of a single-region urban road network, the congestion-protected area a and the area boundary b, where a is the central area of urban traffic, which undertakes the main function of urban traffic and often tends to be saturated or over-saturated form; the area boundary b represents all signal intersections around the congestion-protected area a. Then a macroscopic traffic flow graph for this city can be drawn as shown in Figure 1.
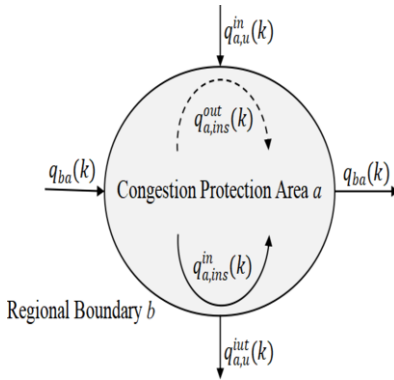
Figure 1 Macro traffic flow of single-region protection area a urban road network
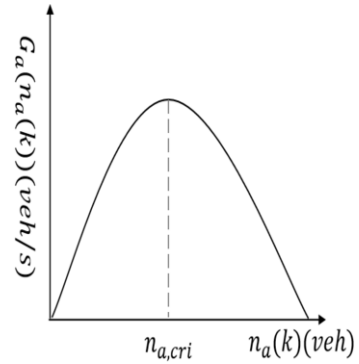
Figure 2 MFD diagram of congestion

First, set the observation time of the road network as an equal sequence of equal steps, i.e. $t = k \cdot T, k = 1,2,3,...,k$, where T denotes the simulation time interval or boundary control interval, and expresses the dynamic process of regional traffic flow in terms of a simple conservation equation for the congestion protection region a, then we have

$$n_a(k+1) = n_a(k) + T(Q_{a,in}(k) - Q_{a,out}(k)) \qquad (2.1)$$

where $n_a(k)[veh]$ denotes the sum of traffic accumulation, or the total number of motor vehicles, in the region a at the kth time step; $Q_{a,in}(k)$ and $Q_{a,out}(k)[veh/s]$ denote the total input and output flows in the region a at the kth time step, respectively. Where $Q_{a,in}(k)$ is calculated as

$$Q_{a,in}(k) = q^{in}_{a,ins}(k) + q^{in}_{a,u}(k) - q_{ba}(k)) \qquad (2.2)$$

where $q^{in}_{a,ins}(k)[veh/s]$ denotes the total traffic demand within the region a at the kth time step; $q^{in}_{a,u}(k)[veh/s]$ denotes the uncontrolled input flow from region boundary b into region a at the kth time step; and $q_{ba}(k)[weh/s]$ denotes the controlled transfer flow from region boundary b to region a at the kth time step.

Second, $Q_{a,out}(k)$ represents the total of the uncontrolled output stream $q_{1,u}^{out}(k)$, the controlled transfer stream $q_{12}(k)$ and the trips ending within region a $q_{a,ins}^{out}(k)$. In addition, $Q_{a,out}(k)$ can also be replaced by the total trip completion rate of region a, $G_a(n_a(k))$, which is expressed by the equation

$$Q_{a,out}(k) = q_{a,ins}^{out}(k) + q_{a,u}^{out}(k) + q_{ab}(k) = G_a(n_a(k)) \qquad （2.3）$$

From the composition of equation （1.3）, it can be seen that $G_a(n_a(k))$ is a non-negative, continuous, convex function with respect to the regional accumulation $n_a(k)(n_a(k) > 0)$, capable of representing the MFD relationship for the congestion-protected region a, as shown in Figure 2, which can be expressed as

$$G_a(n_a(k)) = xn_a^3(k) + yn_a^2(k) + zn_a(k) \qquad （2.4）$$

where x, y and z denote the fitting parameters. The optimal critical accumulation $n_{a,cri}$ is derived from the fitted curve of the MFD and represents the regional accumulation consistent with the maximum trip completion rate.

Substituting equations (2.2) and (2.3) into equation (2.1) yields a discrete dynamic traffic flow equilibrium model for region a, as follows

$$n_a(k + 1) = n_a(k) + T(q_{a,ins}^{in}(k) + q_{a,u}^{in}(k) + q_{ba}(k) - G_a(n_a(k))) \qquad （2.5）$$

3. Real-time streaming and queuing dynamic area boundary control

The so-called boundary threshold, in essence, uses traffic lights to limit the number of motor vehicles entering the protected area of congestion to dynamically adjust the mobility of road network traffic, so as to realize the mechanism of eliminating regional traffic saturation or over-saturation in advance. For a single congestion area, Zhu et al. [3] proposed a discrete boundary feedback control strategy to effectively improve the traffic operation capacity of the road network. However, this strategy also has some shortcomings in practice: first, it fails to fully consider the dynamic characteristics of boundary controlled points; Second, the queuing overflow effect of boundary sections is ignored. Therefore, in the context of considering regional boundaries, this paper proposes a control strategy to optimize regional dynamic boundaries in order to improve traffic efficiency in congested areas.

3.1. Identification of Controlled Boundary Points

At boundary crossings in congestion protection areas, there are often multiple traffic control signals and each intersection presents different traffic operating state. If boundary control is implemented only at road sections with limited remaining storage space, the rate of occurrence of road section overflows problems will be significantly greater than in scenarios without boundary control, ultimately leading to the phenomenon of ineffective boundary control. For this reason, a dynamic boundary controlled point identification technique is required to counteract this.

Firstly, assuming that no traffic flow is generated or completed within the boundary section, i.e. no input port control is performed on all of the boundary sections, then traffic flow monitors are installed on all of the upper, middle and lower sections of the section, with the upper and lower sections functioning to measure real-time traffic flow and the middle section monitors functioning to obtain the hourly occupancy rate. In this case, the number of queuing motor vehicles can be predicted using the Kalman filter, which is given by the formula[4]

$$\hat{x}_{a,m}(k+1) = \hat{x}_{a,m}(k) + T(\mu_{a,m}(k) - q_{ba}^m(k)) + F(x_{a,m}(k) - \hat{x}_{a,m}(k)) \quad （3.1）$$

where m is the mth boundary section within the congestion protection area a; $\hat{x}_{a,m}(k)$ denotes the estimated queuing motor vehicle volume of the mth boundary section at the kth unit time; $\mu_{a,m}(k)$ denotes the real-time monitored arrival flow of the mth boundary section at the kth unit time; and $q_{ba}^m(k)$ denotes the real-time monitoring departure flow, i.e. the changing flow of the mth boundary section from area boundary b to protection area a; F denotes the fixed gain parameter of the Kalman filter. where the equation for real-time monitoring of queuing vehicles $x_{a,m}(k)$ is expressed as[5]

$$x_{a,m}(k) = N_{a,m}^{max} \cdot \frac{L_{ph}}{L_{ph}+\varepsilon} \cdot O_{a,m}(k) \quad （3.2）$$

Where $N_{a,m}^{max}$ denotes the maximum amount of motor vehicles that the mth boundary section can carry; $O_{a,m}(k)$ denotes the time occupancy of the middle monitor of the mth boundary section in the kth unit time; L_{ph} denotes the average value of motor vehicle length; ε denotes the effective range of the middle monitor. where $N_{a,m}^{max}$ denotes the criterion for judging whether the boundary crossing is controlled or not, and its calculation formula can be expressed as[6]

$$N_{a,m}^{max} = \frac{l_{a,m} \cdot \lambda_{a,m}}{L_{ph}} \quad （3.3）$$

where $l_{a,m}$ and $\lambda_{a,m}$ denote the length of the mth boundary section and the number of lanes on the road, respectively.

If $\hat{x}_{a,m}(k+1) < N_{a,m}^{max}$, it means that the mth boundary section meets the minimum requirements for being controlled and can be included in the set of boundary controlled points G_{k+1}; otherwise, the mth boundary section is classified as the set of boundary sections prone to overflow $\bar{G}_{k+1}$.

4. Simulation experiments and analysis of results

4.1. Experimental road network and simulation setup

In this paper, some areas of urban road traffic in a city were selected for simulation testing. Figure 3 shows a simplified diagram of the simulated road based on the VISSIM platform. The network consists of 55 road sections with 25 intersections, of which the points marked in a circle are the 15 boundary sections to be optimized. The data monitoring points for all sections of the area under test are located in the middle of the section, while the data monitoring points are also located upstream and downstream of the section. The core intersections in the area to be tested are marked with triangles and a four-phase signal timing scheme with a signal period of 180 s. The non-core intersections are timed with two phases and a period of 90 s. The speed of traffic in the test section is set between 45 km/h and 50 km/h according to the actual traffic conditions in the city chosen for the experiment.
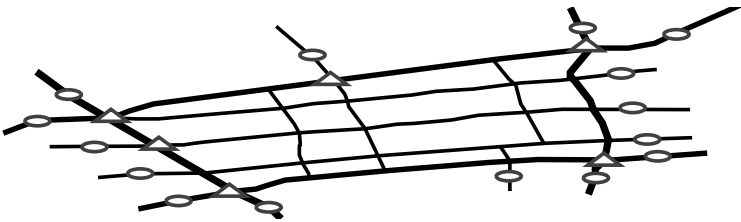
Figure 3. Simulation road network structure of the experimental area

4.2. Calculation of the optimal key accumulation quantity

To ensure the correctness of the MFD fitting results for the area to be tested, then a simulation of unbounded control is done. The traffic demand in the area to be tested is met with input flows from 15 boundary sections, as shown in Table 1. In this case, only a small amount of traffic enters the road network to begin with and increases in proportion to the traffic flow, eventually creating a traffic jam over a while.

Table 1 Input flow rate of the regional boundary section (Unit: veh/h)

Section No.	Simulation time(s)					
	0-900	900-1800	1800-3600	3600-5400	5400-7200	7200-14400
1	900	1800	3600	4800	5400	6000
2	300	600	1200	1600	1800	2000
3	600	1200	2400	3200	3600	4000
4	450	900	1800	2400	2700	3000
5	300	600	1200	1600	1800	2000
6	300	600	1200	1600	1800	2000
7	450	900	1800	2400	2700	3000
8	600	1200	2400	3200	3600	4000
9	300	600	1200	1600	1800	2000
10	750	1500	3000	4000	4500	5000
11	600	1200	2400	3200	3600	4000
12	150	300	600	800	900	1000
13	450	900	1800	2400	2700	3000
14	150	300	600	800	900	1000
15	450	900	1800	2400	2700	3000

Given the inherent randomness of the simulation results, six experiments were conducted under the same demand scenario, with a simulation time of 4h and a simulation step of 180s. Figure 4 shows the scatter plot of the simulation results for each random seed in the six experiments, represented as MFD-i (i=1,2,3,4,5,6). Each discrete point is the traffic accumulation and runs completion flow in the experimental area within 180s. Based on this data, the MATLAB tool was applied to fit the MFD of the experimental area, and the corresponding fitted curve was obtained as the solid grey line in Figure 5, whose curve model can be expressed as $G_a(n_a(k)) = 4.0852 \times 10^{-8} \times n_a^3(k) - 0.000394 \times n_a^b(k) + 0.9828 \times n_a$. The regional accumulation of vehicles reaches 1700 when it lies at the peak of the MFD curve, which is the maximum run completion rate. For this reason, 1700 vehicles are taken as the optimal critical accumulation in the dynamic boundary control strategy in this paper.
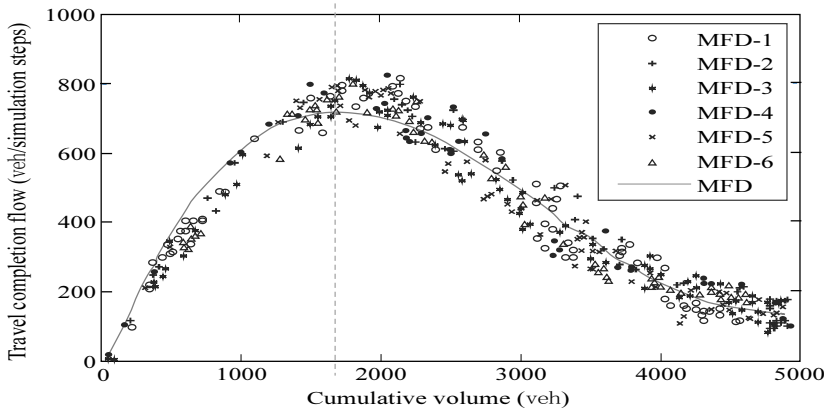
Figure 4 MFD fitting curve of the area to be measured

4.3. Simulation results and analysis of dynamic boundary control

Based on the above-mentioned traffic demand and optimal critical accumulation in the experimental area (Table 1), the duration of the simulation was determined to be 14,400 s with a step size of 180 s. Three different scenarios were simulated: first, a set of well-controlled timing schemes were set up in the experimental area without any traffic restrictions at the boundary intersections, and this scheme was regarded as the basic scheme, i.e., no boundary control, to facilitate comparison with other scenarios. The second is to use the same intersection signal control strategy as in the no-boundary control case, while the signal timing is modified with the boundary control strategy, i.e. the comparison scenario; the third is the proposed scheme with no-boundary control and dynamic boundary control, i.e. the approach of this paper.

The three experimental environments were set up with six replicate simulations each, and the effectiveness of each scenario was compared by regional run completion flows, average vehicle speeds and average delays. Table 2 shows the averages of the simulation results based on the three evaluation metrics, where the run completion flow represents the total number of motor vehicles leaving the experimental area in each simulation time unit; the averages of vehicle speed and delay are mainly shown for the full range including the boundary sections. The comparison with the no-boundary control case reveals that the proposed strategy in this paper improves the run completion flow by 45.90% and increases the average speed by 19.03%, which is higher than the 35.99% and 11.79% of the comparison method; the average delay under this paper's method is reduced by 35.47%, which is also greater than the 26.83% reduction of the comparison method. For this reason, the method in this paper contributes more to the operational effectiveness of the traffic flow compared to the comparison method and the borderless control.

Table 2 Comparative analysis of traffic operation performance

Performance Indicators	Boundaryless control	Comparison Method	Method of this paper	Comparison method improvement	Methodological improvements in this paper
Travel completion flow (veh)	416	569	602	35.99%	45.90%
Average speed (km/h)	26.98	31.07	31.25	11.79%	19.03%
Average delay (s/veh)	273	195	179	26.83%	35.47%

Figures 5 to 7 show the results of a single complete simulation under the three control strategies. It is not difficult to obtain the results from these plots: in the beginning, within a certain phase range (0 to 2300s), it is the kind of control strategy that has a similar effect, while as the number of vehicles approaches the optimal critical value, the boundary control strategy starts to be triggered, including the comparison method and the method of this paper.

Figure 5-1 indicates that the two boundary control scenarios would be triggered at 2300s, with different control results occurring with the input flows. As shown in Figure 5-2, the vehicle entry becomes less in the no-boundary control scenario due to traffic congestion. The boundary input flow under the control strategy of the comparison method also decreases significantly after several fluctuations and is similar to the no-boundary case for about half an hour, as shown in Figure 5-1. The dynamic boundary controlled strategy used in this paper exhibits more stable input flow control and is of better practical value.
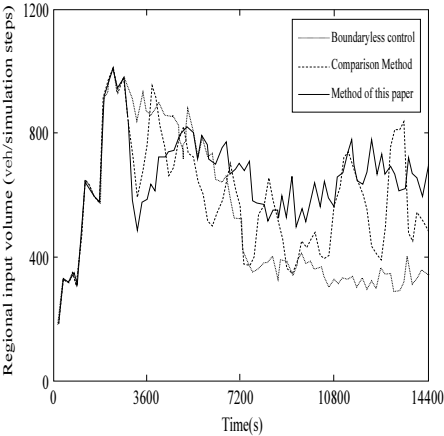
5-1 Regional input flow variation graph   5-2 Travel completion flow change graph
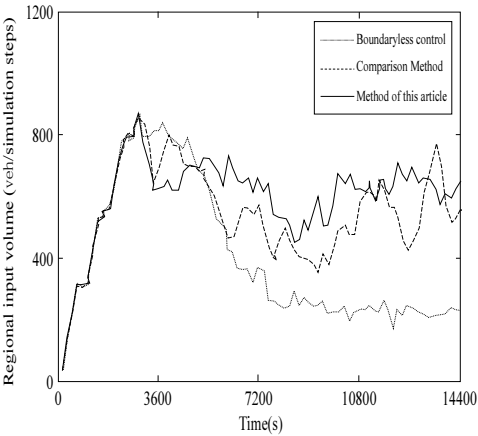
Figure 5 Boundary flow variation in the experimental area

Figure 7 shows the dynamics of the number of controlled boundary sections for the application of the method in this paper. Under the dynamic boundary control strategy, the proposed strategy is able to maintain the accumulation volume in the area to be measured around the optimal critical value. As can be seen from Figure 6, during the last 1h of the simulation, the actual accumulation volume under this strategy is not significantly different from the expected optimal critical value, which is significantly better than the comparison strategy. The dynamic change graph in Figure 5-2 also shows that during the last 1h, this method still marks a high output flow rate, which

is essentially the same as the change in accumulation in Figure 6. The method in this paper significantly outperforms the comparison method in terms of run completion flow for the simulation experiment.
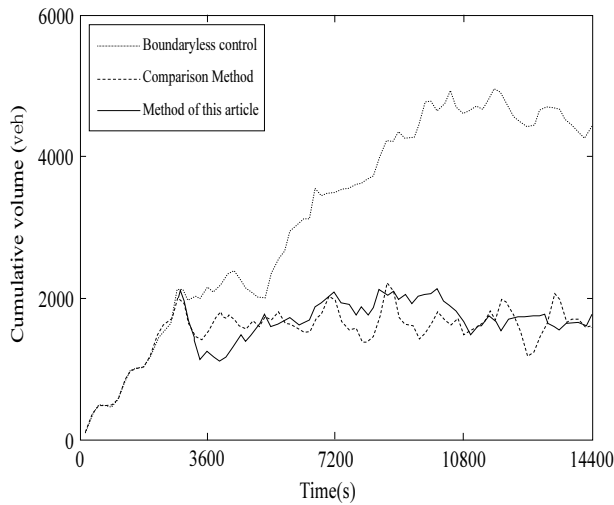
Figure 6 Variation of accumulation in the experimental area
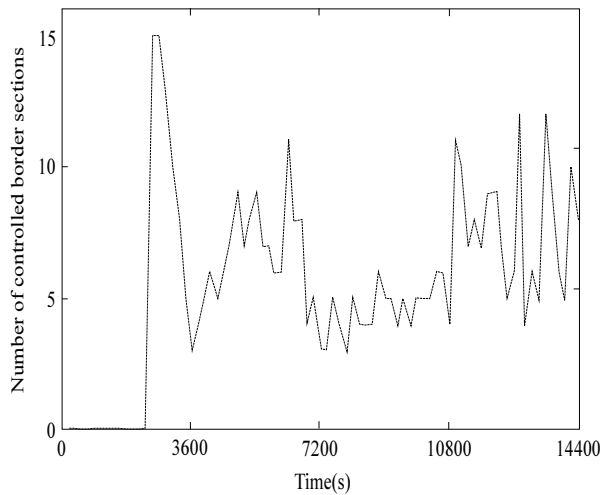
Figure 7 The variation of the controlled number of regional boundary sections of the method

5. Conclusion

Based on MFD theory, this paper proposes a regional dynamic boundary control strategy for the urban road congestion problem of single-region urban networks. Firstly, a traffic flow model to cope with a single congestion-protected region is constructed based on MFD theory; secondly, the Kalman filter method is applied to

realize real-time prediction of motor vehicle queue lengths on boundary sections and a dynamic boundary controlled point identification method is proposed; thirdly, based on the above two points, signal timing optimization of dynamic boundary intersections is given based on real-time flow and queue dynamics data at the regional boundary strategy.

References

[1] Sirmatel Isik Ilber et al. Modeling, estimation, and control in large-scale urban road networks with remaining travel distance dynamics[J]. Transportation Research Part C, 2021, 128

[2] Batista S.F.A. and Leclercq Ludovic and Menéndez Mónica. Dynamic Traffic Assignment for regional networks with traffic-dependent trip lengths and regional paths[J]. Transportation Research Part C, 2021, 127

[3] Zhu W X , Li S . Study on discrete boundary-feedback-control strategy for traffic flow based on Macroscopic Fundamental Diagram[J]. Physica a: Statal Mechanics and its applications, 2019, 523.

[4] G. Vigos, M. Papageorgiou, Y. Wang. Real-time estimation of vehicle-count within signalized links[J]. Transportation Research Part C: Emerging Technologies, 2008,16(1):18-35.

[5] Saad M Khaleel,Gandhi G Sofia,Ali J Kadhim. Development of Vehicle Queue Model for Selected Signalized Intersections at CBD in Sulaymaniyah City[J]. IOP Conference Series: Materials Science and Engineering,2019,518(2):1-8.

[6] Zhang Weihua, Chen Sen, Ding Heng. Feedback valve control considering traffic congestion at boundary intersection [J]. Control theory &applications,2019,36(02):241-248.

Solar Powered Ice Maker System in Karimunjawa Island, Indonesia

Yuli Setyo INDARTONO[a,b,1] and Andhita MUSTIKANINGTYAS[a]

[a] *Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Bandung, Indonesia*
[b] *Research Center on New and Renewable Energy, Institut Teknologi Bandung, Bandung, Indonesia*

Abstract. The solar-powered ice maker was developed in Kemujan, Karimunjawa island, Indonesia. It was powered by 6.66 kWp of solar PV, 19.2 kVAh battery storage, as well as 2 kW of solar ice maker machine, and connected into the utility grid (PLN). Solar energy is applied in this system to minimize utility grid consumption, which is produced by a diesel generator. The hierarchy of the energy supply was PV, batteries, and PLN, respectively. The system is capable to produce 180 kg of ice per production cycle, with a production cycle duration of roughly 20-27 hours. On cloudy days, the renewable energy penetration is around 15-19%. The COP of the ice maker machine is 1.02 and 1.45 for production cycle with ambient brine water temperature and low brine water temperature, respectively.

Keywords. Solar, ice maker, PV, battery, renewable energy penetration, COP

1. Introduction

Solar energy, as one of non-combustible energy takes an important role in the world's energy supply from the renewable energy sector, due to the sun's unlimited source. As shown in Figure 1, solar energy is the largest non-combustible energy sector. Earth receives huge amounts of incoming solar radiation each day. Thirty percent of this sun light is reflected back into the atmosphere, and the rest is absorbed by plants, sea water, buildings, etc. Solar radiation on the earth's surface is equal to almost 1,366 W each day [1]. This energy source can easily be converted into electricity without going through a power generation cycle. It can be directly used by photovoltaic (PV) cells or converted into thermal energy by using solar thermal collector.

The solar energy has been applied for some activities, both in the form of PV cells or thermal collectors. It has been implemented for electricity generation as PV power plant, for domestic or household use as rooftop PV and solar water heaters, and for productive use as well. Solar application for productive use is the application of solar energy to enhance the social economic aspect by giving service in agricultural, commercial, and public industrial activities [3]. It has been popular since it is deemed more useful for people with limited access to the electricity.
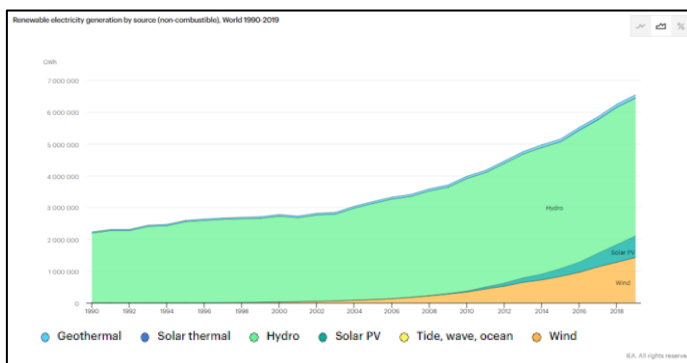
Figure 1. Total primary energy supply composition from renewable energy non-combustible process [2].

One example of the solar application for productive use is solar ice maker for fishermen in a rural area. The feasibility of utilization of solar energy as renewable energy to power the ice maker machine is questionable; therefore, the techno-economic analysis should be performed to identify the feasibility of this system implementation in Indonesia. One of solar ice makers that is being operated in Indonesia is located in Karimunjawa. Karimunjawa is the islands located in Jepara regency, Central Java Indonesia that consists by four inhabited islands, e.g., Karimunjawa, Kemojan, Parang, and Nyamuk island. The total area of those islands reaches 71.2 km^2 with 9,514 population [4]. Most of the population works as active fishermen, while the rest are fishing periodically. The fishermen need tons of ice cubes each day for fish or seafood storage. There is a need to produce ice blocks as fish storage by ice maker machine. The ice maker machine needs high energy to operate, therefore it requires a huge electricity bill to operate the ice maker machine. Solar photovoltaic (PV) could become a solution to this challenge, since as a tropical area Karimunjawa has global horizontal irradiation of up to 1,818 kWh/m2 [5].

The solar-powered ice maker in Kemujan, Karimunjawa island, initially was developed by Ali. M, et al, [6]. The system used 5 kWp of PV and 3 kW biobased diesel engine generator as a power generator. Five kW bi-directional inverter regulated the power generator, 16 pcs of battery 100 Ah/12 V 5 kW, and the ice maker. The system produced 120 kg ice per 62.5 hours with a total energy requirement of 121.591 kWh. Indartono, et al [7] had connected the previous system with the utility grid and used a bio-based diesel generator as backup power. In this study, the system which was developed by Indartono, et al [7] is improved by increasing the PV capacity and implementing a gap between PV and roof to reduce the surface PV temperature.

2. Ice Maker Machine in Kemujan, Karimunjawa

The ice maker machine design is shown in Figure 2. The machine used the secondary refrigeration principle since it used brine water for water cooling inside the ice container. The machine consisted of the below components:

    a. The brine water tank, for brine water cooling. The ice container was being submerged in the brine water for the cooling process. The brine water is used as a secondary cooling agent, with a 20% concentration of salt.

b. The ice container tank, contained 6 containers with 30 kg in each. There was baffle in this tank to help brine water circulation. The baffle configuration was shown in Figure 3

c. Refrigeration machine: compressor, condenser, and drier.

d. Pump, with the suction from brine water near ice container tank and the discharge flow into the outside evaporator coil. The pump was occupied to circulate the brine water, in order to accelerate the heat transfer and to prevent salt deposition.

e. Evaporator coil, to circulate the refrigerant inside the coil. The refrigerant used in the machine was hydrocarbon refrigerant R-290 (Propane).
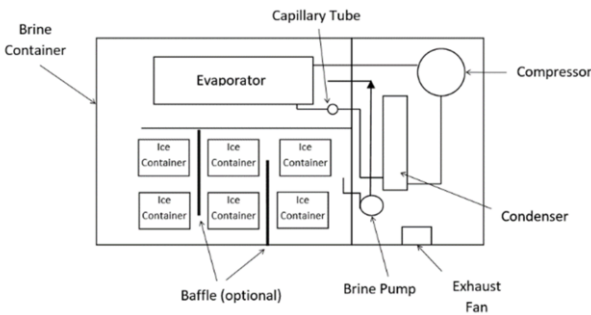
Figure 2. Ice maker machine design [7].

3. The Smart Grid System in Kemujan, Karimunjawa

The experiment in the Kemujan site was conducted to find out the system performance of smart microgrid systems and ice maker machines. The testing scheme was arranged as per Figure 3. The 4 strings monocrystalline PV (total 12 PV) 295 Wp and 3 strings polycrystalline PV 260 Wp (total 12 PV) were arranged and connected into a smart grid inverter 10 kW and battery. The national utility grid (PLN) was connected into the system in bypass connection, which means the utility grid does not take a part in battery charging in order to minimize the cycle use of the battery to lengthen the battery lifetime.
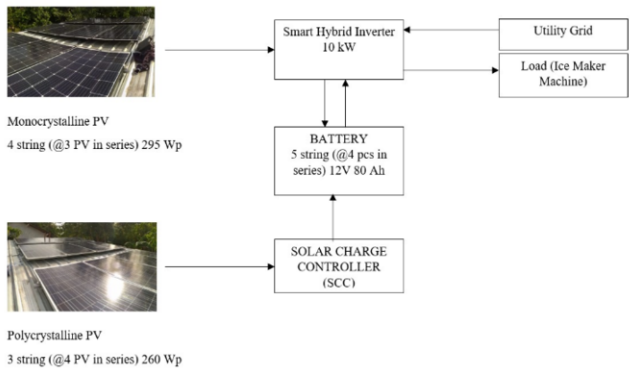
Figure 3. Real-scale testing at Kemujan site.

4. The Smart Grid System in Kemujan, Karimunjawa

4.1. Design Comparison

In this study, PV capacity was increased become 6.66 kWp (previous system was 5 kWp). Comparison between the new and the existing design is shown in Table 1.

Table 1. Design comparison of this study and the previous design.

Parameter	Previous Design [7]	This study
PV Capacity	5 kWp	6.66 kWp
Implemented Gap/PV tilt	0 cm / 10°	13.5 cm / 10°
PV Productivity	5.762 MWh/year	8.412 MWh/year
Cycle time	30 – 62.5 hours	20 – 27 hours

The PV productivity in a year was simulated by PVSyst software with considering the shading and geographical coordinate of the site. From Figure 4, the highest PV productivity is in August to September and the lowest is in December to January, since those months have a rainy season.

From Figure 4, the PV productivity in December is 0.489 MWh/month. In a day, the theoretical PV power output should achieve 15.77 kWh/day. The design simulation result would be utilized as a basic comparison with the real-scale experiment which explained in the next section.
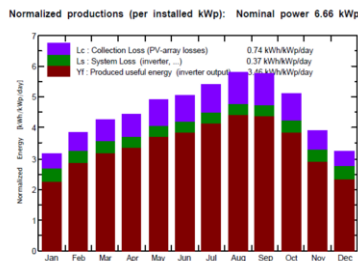
Figure 4. PV productivity prediction in a year of Kemujan site.

4.2. Supply Power Analysis of Smart-Grid System

During operation, several inverter operation modes occurred depending on the solar irradiance supply and battery power discharge rate. Since the operation used the SBU (Solar-Battery-Utility) set-up, the inverter will prioritize solar energy from PV. The second hierarchy is the battery supply. If solar energy is not sufficient, the battery will help to supply the loads at the same time. Utility grid (PLN) will supply the system if only if the battery and solar power are not adequate to supply the load. In addition, the charging mode tested during the operation was OSO (Only Solar) means that the battery was charged using solar energy only. It was chosen to minimize the battery cycle, in order to lengthen the battery shelf life. The following explanation describe the analysis of each operational mode.

a. PV Charge and Bypass
   This mode allowed PV simultaneously with the utility grid to power the load since the solar energy itself was not adequate to supply the load and the battery voltage lower than 56 V. This operation mode occurred when the weather was

cloudy with severe rains. The irradiance and PV power during this time was shown by Figure 5. The trend showed by PV power was following the solar irradiance entering the PV surface. During this operational mode, the battery voltage was floating in the value of 52-53 V shown in Figure 6.
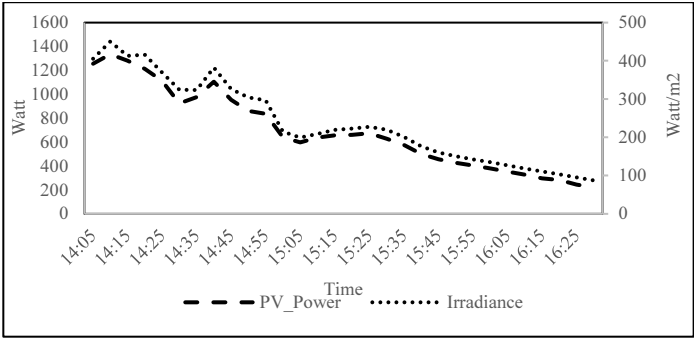
Figure 5. PV Power and Irradiance during the cloudy day (PV charge and Bypass operational mode).
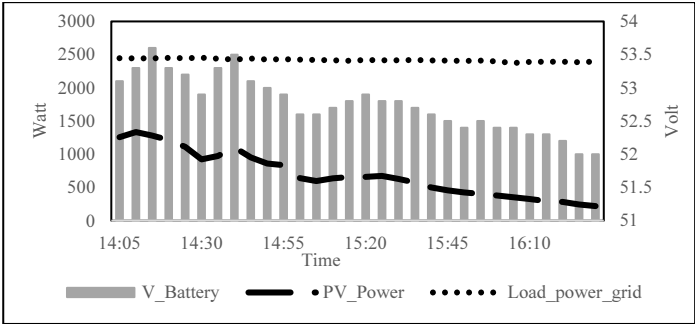
Figure 6. Supply power for the load during PV Charge and Bypass operational mode.

b.   PV Charge and Discharge
     This condition occurred when solar energy and battery simultaneously power the ice maker machine. The set-up for battery discharging voltage was 44.8 – 56 Volt. The battery started to discharge when the battery voltage was equal to 55.4, which is close to 56 V as voltage discharge set-up. From Figure 7, it could be seen that the PV power was higher than the ice maker load at some points. In this condition, the battery pause discharging and the load was fully supported by solar energy. The battery stopped discharging when its voltage was equal to 44.9 Volt, which is near to 44.8 as set-up discharge voltage.
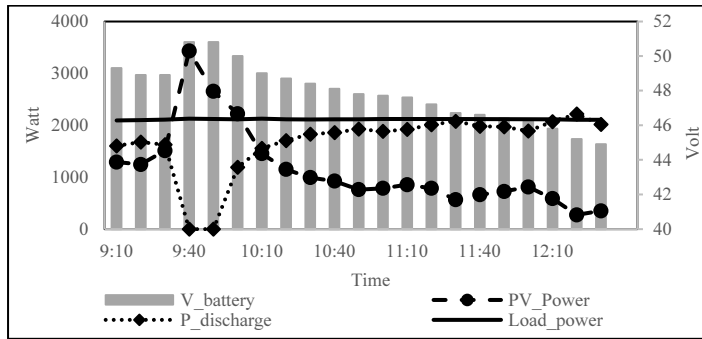
Figure 7. The supply power on PV Charge and Discharge operational mode.

c. Discharge

The discharge operational mode occurred when there was no solar energy and the battery was fully charged, therefore it did not utilize the utilization grid electricity. This condition usually happens during the night operation. From Fig 8, it can be determined that the battery voltage was decreasing along with the ice maker machine operation. The actual battery voltage discharge range was 45.1 - 55.7 V.
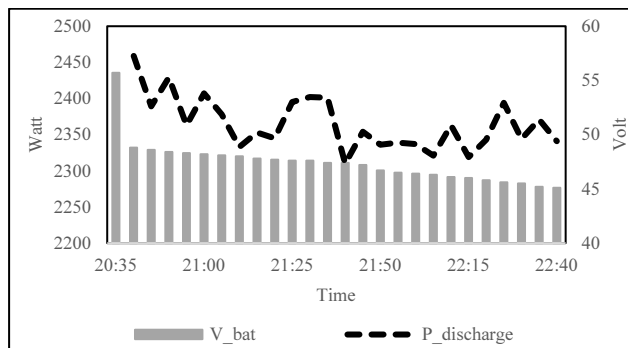
Figure 8. Battery analysis during discharge operational mode.

In the overall process, the interaction among PV, grid (PLN), and the battery are shown in Figure 9. The mode changed along the fluctuate of the battery voltage since the battery voltage indicates the battery state of charge.

The inverter efficiency evaluation shows that it varies with the operation mode. The values of each mode are shown in Table 2 below. Inverter efficiency has a higher value on the AC charge mode than during battery or PV charging. It is due to the power supply from the grid (PLN) does not need the conversion process, unlike what happens during battery charging or PV supply.
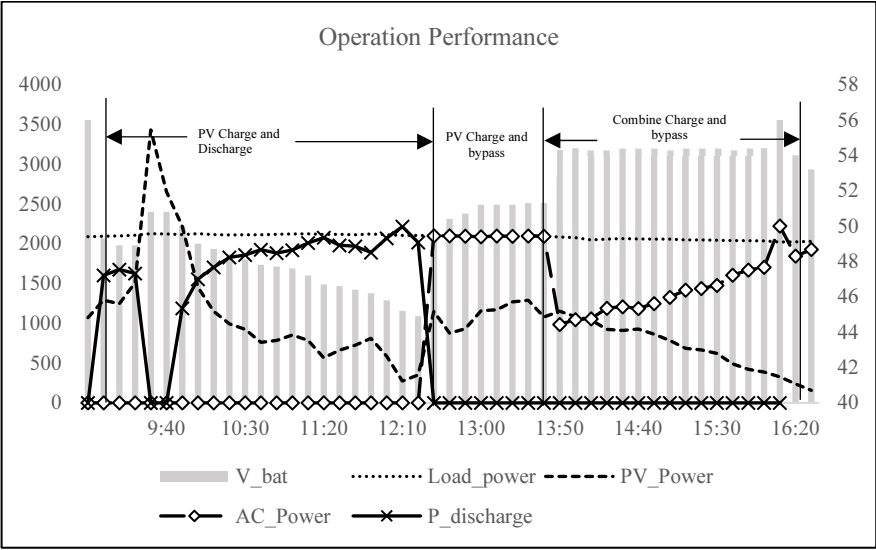
Figure 9. The interaction among PV, grid (AC Power), and Battery.

Table 2. Inverter efficiency based on operational mode.

Operation Time	Operation Mode	Inverter Efficiency
Morning-afternoon	PV Charge and Bypass	76.5 %
	PV Charge and Discharge	77.65 %
Evening	AC bypass + Battery discharge	91.28%

4.3. Energy Analysis of Smart-Grid System

The energy analysis of both ambient temperature and low temperature of brine water is shown by below table.

Table 3. Energy supply summary of ice production cycle.

Parameter	Ambient brine water temperature	Low brine water temperature
Grid electricity used	52.94 kWh (IDR 76,476)	42.4 kWh (IDR 61,261)
Load total	60. 39 kWh	43.97 kWh
PV productivity total	12.19 kWh (19% of total energy)	7.4 kWh (15% of total energy)
Production time	27 hours 10 minutes	20 hours 45 minutes
Total inverter efficiency of system	94 %	88%

From the table above, it can be concluded that the PV can contribute 15-19% of the load electricity needed. The PV productivity in Table 1, mainly for ambient brine water temperature, was close with simulation results by using PVSyst. The selling price of ice production was IDR 120,000. Therefore, the net profit from one production cycle is approximately IDR 40,000 – IDR 60,000.

4.4. Performance of Ice Maker Machine

The experiment in Kemujan site was conducted in 2 different initial brine water temperature. The first production cycle utilized ambient brine water temperature, while the second cycle is using the lower temperature of brine water since it was already cooling down from the first cycle. The latent phase of these 2 production cycles was taking approximately 18-19 hours. The total duration of the ambient brine water production cycle was taking 27 hours 10 minutes, while the low brine water production cycle had a 20 hours 45 minutes duration. Figure 10 shows the ice block product. Overall, the ice block product has a good quality and is acceptable for fishery grade.

Figure 10. The ice block production (total 6 ice blocks).

Ice maker machine in Kemujan site has 2 kW compressor power. The performance calculation is stated as COP (Coefficient of Performance) or the ratio between refrigeration capacity and the compressor power. The refrigeration capacity is calculated from heat transfer absorbed by the evaporator from the brine, while the compressor work was measured using kWh meter. The COP of the cycle with ambient brine water temperature was 1.02, while the second cycle (low brine water temperature) produced a lower COP of about 1.45.

5. Conclusion

The existing solar-powered ice maker from previous research was improved by increasing the PV capacity. During the cloudy situation, solar energy could provide around 15-17% of total energy. Some different operation modes were applied during the experiment. The PV, utility grid, and battery were working simultaneously to supply the load. The system could produce 180 kg of ice block for 27.16 hours when the water is started from the ambient water temperature. The shorter duration of ice production occurred in the low brine water temperature, which only needed 20.75 hours of production time. The COP of ice maker machine is 1.02 and 1.45 for ambient brine water temperature and low brine water temperature, respectively.

Author Contributions

Indartono, Y.S. design the system & experiment and finalize the manuscript. Mustikaningtyas, A. did experiment on smart grid and ice maker performance, and also prepare the manuscript.

References

[1]   Mohd RSS, Santosh BW, Suvarna SL, Pooja VF, Anil T. A review paper on electricity generation from solar energy. International Journal for Research in Applied Science & Engineering Technology. 2017 Sep; 5 (IX):1884-9.

[2]   Renewable Energy Generation from the Source (Non-combustible), get the data from IEA Data & Statistics is accessed via https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=RenewGenBySource on 07 Nov 2020.

[3]   Photovoltaic for Productive Use Application, implemented by GIZ. Downloaded via https://energypedia.info/images/archive/9/98/20160610130718%21GIZ_%282016%29_Catalogue_PV_Appliances_for_Micro_Enterprises.pdf on 07 Nov 2020

[4]   BPS Kabupaten Jepara (2018): Kecamatan Karimunjawa dalam Angka 2018. BPS Kabupaten Jepara ISSN 2614-9036.

[5]   https://globalsolaratlas.info/map?c=-5.879626,110.432907,11&s=-5.879626,110.432907&m=site accessed on 01 Feb 2020

[6]   Ali, M. (2018): Design and development of smart micro grid system based on renewable energy for fishermen's ice maker machine, Master's Thesis, Institut Teknologi Bandung.

[7]   Yuli Setyo Indartono, Musfirin, Aldrin (2021): Development of smart micro grid to operate ice maker in remote island in Indonesia, Conference Proceedings ASEAN Energy Transition with Resiliency in the Post-Pandemic Climate Change Era, the 1st ASEAN International Conference on Energy and Environemt, 15 September 2021 – Virtual Conference.

Lightweight Gesture Pose Estimation Based on CPM Algorithm

He WANG[a,1], Qingjiang YANG[a], Qiang WANG[b] and Liang YU[a]

[a] *Heilongjiang University of Science and Technology, College of Electronic and Information Engineering, Harbin 150022, China*
[b] *Yanshan University, School of Vehicle and Energy, Qinhuangdao 066000, China*

Abstract. With the experiential enhancement of artificial intelligence products, gesture estimation, as a classic computer vision task, has a wide range of application scenarios. Aiming at the current network model that needs to be lightweight in mobile smart products, this paper designs a lightweight gesture pose estimation model based on the CPM (Convolutional Pose Machine) multi-stage human pose estimation network. A comparative experiment based on the RHD open-source data set was conducted to compare and analyze the lightweight CPM gesture estimation model while ensuring accuracy while effectively reducing the amount of model parameters, which provides a basis for the development of real-time mobile terminal gesture pose estimation.

Keywords. Convolutional pose machine, gesture pose estimation, lightweight

1. Introduction

Pose estimation is to connect joint points to judge the state and behavior of human body parts [1]. Two methods are included by Pose estimation, which are top-down [2] and bottom-up [3]. And meanwhile, the gesture posture, as an important part of human posture, is a way to accurately locate the positional relationship between the key points of the hand, and then to infer the corresponding posture estimation method. According to research methods, gesture pose estimation can be divided into three methods: Generative Methods [4], Discriminative Methods [5] and Discriminative methods and Generative methods [6]. The generation method is to match the input image with a pre-defined hand model. The discriminant method is a method of directly positioning the hand joints based on the appearance of the input depth image. Random forest [7] is a more traditional discrimination method, which can quickly and accurately process a large number of input variables, but for the shortcomings of self-occlusion and low resolution of the hand depth map, there are a lot of errors in its results. The processing method of gesture estimation using convolutional neural network is constantly overcoming these problems [8-9]. Tompson et al. [10] used CNN for the first time to locate the key points of the hand and estimate the 2D hot soil of each joint point for estimation. Ge et al. [11] directly converted the 2D input depth map into estimated 3D coordinates through 3D CNN. The hybrid method, which combines the generation method and the discriminant method, uses the discriminant method first, and then corrects the result by the generation

---

[1] Corresponding Author, He WANG, Heilongjiang University of Science and Technology, No. 2468, Puyuan Road, Songbei District, Harbin, Heilongjiang; E-mail: 2250293019@qq.com.

method. Ye et al. [12] used a hybrid method to estimate gestures in a multi-stage and hierarchical manner, which has good robustness. Hwang, J et al. [13] used a simple K-means clustering algorithm to explore unusual poses that are rare which occupy a small portion in a pose dataset. B Artacho et al. [14] proposed OmniPose, a single-pass, end-to-end trainable framework, that achieves state-of-the-art results for multi-person pose estimation. Hietanen, A et al. [15] introduce an approach that connects error in pose and success in robot manipulation, and propose a probabilistic performance measure of the task success rate.

We are in the era of the popularization of big data, and electronic products such as artificial intelligence have emerged one after another, and have achieved remarkable development. With the introduce of deep learning, more advanced and novel methods such as human body gesture recognition and gesture estimation in the field of human-computer interaction have relatively broad application prospects. Of them, gesture estimation based on machine vision, as one of the core technologies of human-computer interaction, has made good progress. In summary, posture estimation of gestures is a task that involves the intersection of natural language processing, pattern recognition, and computer vision. The effective estimation and recognition of gestures has promoted the advancement of machine learning and other fields, and has accelerated the process of globalization, so it has certain research significance.

With the development of computer vision, gesture estimation is often used in many scenarios such as human-computer interaction and video surveillance. Generally, convolutional neural networks have a large amount of parameters and calculations, which cannot be applied to mobile terminals or embedded devices. In order to better implement real-time gesture pose estimation on mobile terminals or embedded devices, the network model needs to be lightweight. Based on the multi-stage convolutional pose machine CPM (Convolutional Pose Machine) network in human pose estimation [16], this paper designs the gesture pose estimation network. At the same time, a lightweight network is designed to ensure the accuracy and stability. The above reduces the parameter amount of the model.

2. CPM Algorithm

The Convolutional Pose Machines (CPM) algorithm is a multi-stage pose estimation network based on serialized fully convolutional network structure and learning spatial information. It integrates the convolutional network into Pose Machines to learn image features and image-related spatial models; a serialized structure composed of a full convolutional network. The convolutional network is directly operated on the belief maps of the previous stage. Output more refined joint point position estimation results to handle structured prediction tasks; an end-to-end learning network that uses intermediate supervision loss to solve the problem of gradient disappearance. As shown in Figure 1, the CPM algorithm is a multi-layered network structure composed of a multi-stage convolutional neural network. It generates a confidence map through the convolutional neural network of each stage, and then predicts the position of each key point in each stage. Among them, gt represents the convolutional neural network of each stage, bt represents the confidence map, and uses t to represent each stage in the multi-level sequential structure, and when t>1 becomes the strengthening stage.

For the initial stage, the feature extraction network is used to extract features from the image, and the position confidence of each location is predicted by g_t. For the

enhancement phase, the CPM network uses a feature extraction network to re-extract features from the original image, and map and merge it with the confidence map of which phase. Through the phase loss function value obtained at the end of each phase, the CPM algorithm is locally supervised.
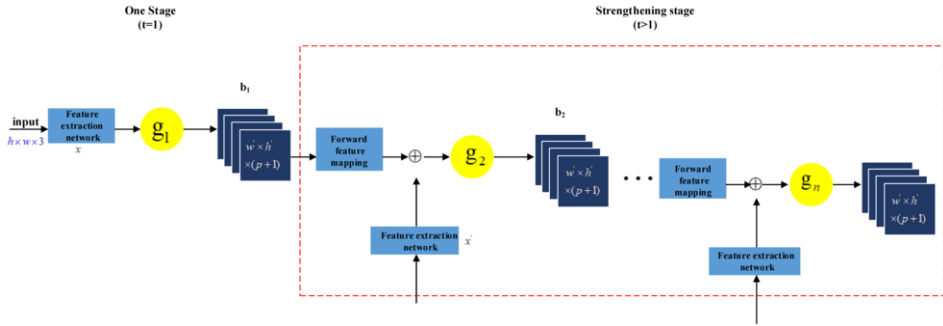
Figure 1. Convolutional attitude machine CPM network diagram.

At the same time, the CPM algorithm has the disadvantage that a large amount of computing power is required to extract the original image features each time because the feature extraction network is not unified. In addition, CPM needs to perform forward mapping features during the enhancement phase, which consumes a lot of computing power and is more complicated.

3. CPM Lightweight Gesture Pose Estimation Algorithm

CPM (Convolutional Pose Machine) pose estimation network is often used for human pose detection. Based on the idea of CPM multi-level sequential pose estimation network, this paper will design the network structure and apply it to gesture pose estimation. In view of the huge amount of calculation in the process of extracting features by the CPM algorithm, this paper changes part of the standard convolutional layer structure to a deep separable convolutional layer, and merges the losses in each stage to obtain a lightweight CPM gesture pose estimation network. It provides a basis for real-time estimation and detection of gesture estimation on mobile or embedded devices.

3.1. CPM Gesture Network Pose Estimation Structure

The structure composed of the convolution structure and the attitude machine structure is called the convolution attitude machine [17]. This structure can automatically learn features from the training data set, and inferentially learn the distance structure relationship between key points, which can be applied the location of the key points in the gesture pose estimation in this paper.

The process of the migrated CPM hand posture estimation network to return the coordinate position information of the key nodes of the image is: use the response heat map heatmap and feature map representing the spatial constraint information between the various joint points as data to be transmitted in the network; use the multi-stage convolutional neural network conducts supervised training and processes the response information of key nodes. The detailed structure of the algorithm is shown in Figure 2.

From the structure diagram of the CPM gesture posture estimation network, it can be seen that the network is performing the overall process of hand posture estimation. Among them, the convolution part of the CPM pose estimation network includes
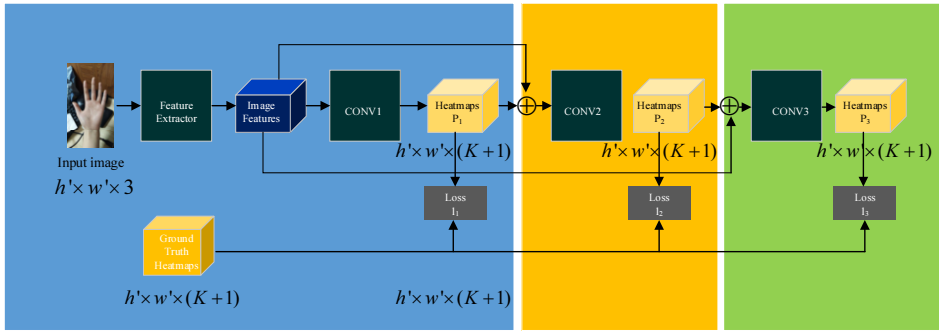
Figure 2. CPM gesture posture network structure diagram.

convolution and maximum pooling layers. The network modified based on the VGGNet network is used for backbone feature extraction network features. In the figure, CONVx (x=1,2,3) is composed of a series of convolutional layers and pooling layers.

The CPM pose estimation network is a multi-stage prediction network. Based on the topological relationship between the key points of gestures, the accuracy requirements of gesture pose estimation can be met by using a lower stage. Therefore, the CPM gesture pose estimation network used in this paper contains a total of three stages. The heat map of each stage is used to characterize the position information of the key nodes, and the stage corresponding to the smaller receptive field is located in the previous stage of the network, so the relative error of the obtained prediction result is relatively large. The later stage of the enhancement layer corresponds to a larger receptive field, and the context information and image features of the previous stage can be obtained, so the prediction result with relatively small error is obtained. This staged posture estimation network can make a step-by-step more accurate reasoning of the hand posture, and finally fuse the obtained loss values to obtain the final predicted joint point position information.

In view of the mobile terminal or embedded pose estimation task, a lighter model is required. In order to reduce the overall parameter amount of the model, the convolution kernel in the three-stage CPM gesture pose estimation network is replaced with 1*1 and 3*3 convolution kernel. This method can more accurately estimate the key point positions and reduce the amount of model parameters, and obtain a lighter gesture pose estimation network.

3.2. The Introduction of Deep Separable Convolutional Layers

Depth separable convolution is a kind of factorized convolution realized by decomposing ordinary convolution into two parts of deep convolution and 1*1 point-by-point convolution. In the first step, the deep convolution operation uses a single convolution and a lightweight filtering operation on the input channel, that is, to realize the convolution operation of the convolution kernel and the feature map one by one. In the second step, a 1*1 convolution kernel is used to perform a point-by-point convolution operation on the basis of the previous feature map, and the output feature maps are linearly combined. Compared with the one-step operation of the ordinary convolutional layer, the depth separable convolution uses two steps of deep convolution and point-by-point convolution to convolve a single channel and then combine them. The parameter amount and calculation amount of the model can be greatly reduced. Among them, the comparison structure diagram of the standard convolutional layer and the depth separable convolutional layer is shown in Figure 3.
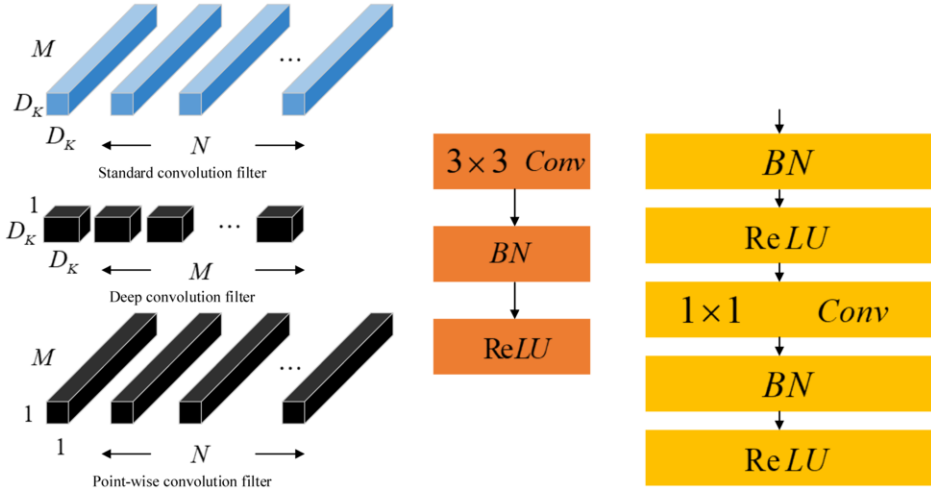
Figure 3. Comparison of ordinary convolutional layer and depth separable convolutional layer.

Among them, the calculation amount and parameter amount of the depth separable convolution and the standard convolution layer are compared as follows [18]:

Calculation amount of standard convolution:

$$D_K \times D_K \times N \times M \times D_F \times D_F \tag{1}$$

Parameters of standard convolution:

$$D_K \times D_K \times N \times M \tag{2}$$

The amount of calculation for deep convolution:

$$D_K \times D_K \times 1 \times M \times D_F \times D_F \tag{3}$$

The amount of calculation for point-by-point convolution:

$$1 \times 1 \times N \times M \times D_F \times D_F \tag{4}$$

The parameters of the depth convolution:

$$D_K \times D_K \times 1 \times M \tag{5}$$

The number of parameters for point-by-point convolution:

$$1 \times 1 \times N \times M \tag{6}$$

The parameters of the depth separable convolution:

$$D_K \times D_K \times M + N \times M \tag{7}$$

The amount of calculation for the depth separable convolution:

$$D_K \times D_K \times M \times D_F \times D_F + N \times M \times D_F \times D_F \tag{8}$$

The above formula shows that deep separable convolution can greatly reduce the amount of network parameters and calculations. Therefore, this paper introduces deep separable convolution to replace part of the convolutional layer structure in the CPM multi-stage attitude estimation network, resulting in a lighter weight CPM gesture pose estimation network.

4. Experiments and Results

4.1. Experimental Environment and Data Set

The environment used in this paper is anaconda+keras2.24+TensorFlow1.14+cuda9.2, graphics card NVDIAGTX2080.

This paper uses the RHD [19] open source gesture and pose dataset as the training dataset. This dataset is a gesture dataset of synthetic RGB images composed of 41258 training images and 2728 test images. It is obtained by asking 20 different mannequins to perform 39 different actions randomly and then generating arbitrary ones after all. Due to the huge changes in the viewpoint and hand ratio, and the huge visual differences caused by the random noise and ambiguity of the image, the data set is quite challenging. For each RGB image, it provides the corresponding depth image, occlusion label, 2D label and 21 key point 3D label. Figure 4 shows part of the dataset
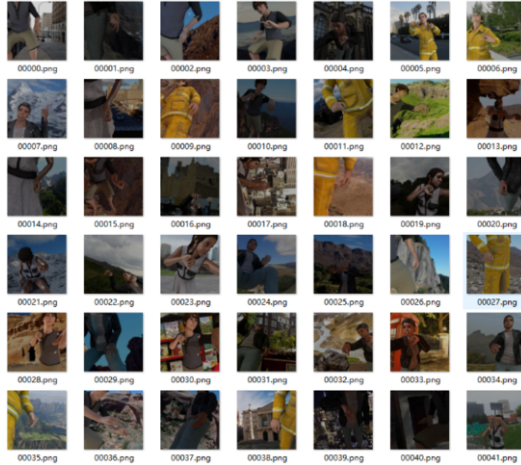
Figure 4. Part of the RHD dataset.

4.2. Training and Evaluation Indicators

We use the RHD data set to divide it into training set, test set, and validation set with a ratio of 8:1:1 for training. Set the Batch size to 8, the initial learning rate is 0.0001, the

number of iterations is 60,000, and the learning rate drops to 10 times at each iteration of 10,000, and the Adam optimization method is used.

4.2.1. Test Set Evaluation Model

This paper uses model accuracy and model size to measure the relative performance of the gesture pose estimation model proposed in this paper.

Model accuracy: PCK (Percentage of Correct Keypoints) means that the normalized distance between the 21 actual keypoints of the gesture and the predicted keypoint is less than the percentage of the specified threshold. Taking the threshold as the abscissa and the PCK as the ordinate, the area under the PCK curve under different error thresholds is drawn as AUC (Area Under Curve, AUC) [20].

As shown in Table 1, compared with the original model performance indicators without lightweight processing, experiments show that when the model accuracy is stable, the size of the model is greatly reduced (here the Loss function is).

Table 1. Lightweight model comparison experiment.

Model	Model accuracy (%)	Model size (M)	Flops
CPM	72.8	24.32	48.62
Lightweight CPM	72.4	6.89	13.77

It can be seen from the table that compared to the original CPM gesture posture estimation network, the introduction of a deeply separable network model for lightweight processing of CPM gesture posture can reduce the model size to about 4 times the original under the premise of ensuring the stability of the model. The Flops value will be about 1/4 times the original value. It can effectively reduce the amount of model parameters and provide a basis for the development of real-time mobile terminal gesture pose estimation.

4.2.2. Visualization of Detection Results

Figure 5 shows the effect of the detection effect on the RHD dataset under the anaconda+keras2.24+TensorFlow1.14+cuda9.2 experimental environment.

Figure 5. Detection effect visualization.

5. Conclusion

With the development of computer vision, gesture estimation is often used in many scenarios such as human-computer interaction and video surveillance. Generally, convolutional neural networks have a large amount of parameters and calculations, which cannot be applied to mobile terminals or embedded devices. In order to better implement real-time gesture pose estimation on mobile terminals or embedded devices, the network model needs to be lightweight. This paper changes the network structure of CPM based on human pose estimation and transfers it to gesture pose estimation. At the same time, the introduction of deep separable convolution to replace part of the convolutional layer structure in the network structure greatly reduces the amount of calculation and calculation of the model.

Experimental comparison and visualization show that the lightweight CPM attitude estimation network can still have good detection results in complex environments such as occlusion and deformation, and can greatly reduce the amount of model parameters and parameters while ensuring stable accuracy. The amount of calculation lays the foundation for real-time running of gesture and posture algorithms on mobile or embedded devices.

References

[1] Ramakrishna V, Munoz D, Hebert M, Bagnell JA, Sheikh Y. Pose machines: articulated pose estimation via inference machines. Lecture Notes in Computer Science. 2014; 33-47.

[2] Cao Z, Hidalgo G, Simon T, Wei S E, Sheikh Y. OpenPose: Realtime multi-person 2d pose estimation using part affinity fields. IEEE Transactions on Pattern Analysis and Machine Intelligence. 2018; 1.

[3] Fang HS, Xie S, Tai YW, Lu C. RMPE: regional multi-person pose estimation, 2017 IEEE International Conference on Computer Vision (ICCV), Venice, Italy, 2017:2353-2362, doi: 10.1109/ICCV.2017.256.

[4] Qian C, Xiao S, Wei Y, Tang X, Jian S. Realtime and robust hand tracking from depth. 2014 IEEE Conference on Computer Vision and Pattern Recognition. IEEE, 2014 :1106-1113.

[5] Ge L, Hui L, Yuan J, Thalmann D. Robust 3D hand pose estimation in single depth images: from Single-View CNN to Multi-View CNNs. 2016: 3593-3601.

[6] Ye Q, Yuan S, Kim T K. Spatial attention deep net with partial PSO for hierarchical hybrid hand pose estimation. 2016:346-361.

[7] Keskin C, Kıraç F, Kara YE, Akarun L. Hand pose estimation and hand shape classification using multi-layered randomized decision forests. 2012:852-863.

[8] Liang H, Yuan J, Thalmann D. Parsing the hand in depth images. IEEE Transactions on Multimedia, 2014, 16(5):1241-1253.

[9] Chen X, Wang G, Guo H, Zhang C. Pose guided structured region ensemble network for cascaded hand pose estimation. Neurocomputing, 2020: 395, 138-149.

[10] Tompson J, Stein M, Lecun Y, Perlin K. Real-Time continuous pose recovery of human hands using convolutional networks. ACM, 2014:1-10.

[11] Ge L, Liang H, Yuan J, Thalmann D. 3D convolutional neural networks for efficient and robust hand pose estimation from single depth images. 2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR). IEEE, 2017: 1991-2000.

[12] Ye Q, Yuan S, Kim T K. Spatial attention deep net with partial PSO for hierarchical hybrid hand pose estimation. 2016: 346-361.

[13] Hwang J, Yang J, Wak NK. Exploring rare pose in human pose estimation. IEEE Access, 2020, 8:194964-194977.

[14] Artacho B, Savakis A. OmniPose: A multi-scale framework for multi-person pose estimation. 2021. arXiv preprint arXiv:2103.10180

[15] Hietanen A, Latokartano J, Foi A, Pieters R, Kmrinen JK. Benchmarking pose estimation for robot manipulation. Robotics and Autonomous Systems, 2021, 143(1):103810.

[16] Liu Z, Cai YF, Wang H, Chen L, Gao HB, Jia YY, Li YC, Robust Target recognition and tracking of self-driving cars with radar and camera information fusion under severe weather conditions, in IEEE Transactions on Intelligent Transportation Systems, doi: 10.1109/TITS.2021.3059674.

[17] Ramakrishna V, Munoz D, Hebert M, Bagnell JA, Sheikh Y. Pose machines: articulated pose estimation via inference machines. European Conference on Computer Vision. Springer, Cham, 2014: 33-47.

[18] Howard AG, Zhu M, Chen B, Kalenichenko D, Wang W, Weyand T, Andreetto M, Adam H, MobileNets: Efficient convolutional neural networks for mobile vision applications. arXiv preprint arXiv:1704.04861, 2017.

[19] Zimmermann C, Brox T. Learning to estimate 3D hand pose from single RGB images. 2017: 4903-4911.

[20] Zhao, B, Zhao, B, Tang, L, Wang, W, Wu, C. Multi-scale object detection by top-down and bottom-up feature pyramid network. System Engineering and Electronic Technology (English Version), 2019, 30(1): 1-12.

Analysis of the Wear Mechanism of High-Speed Transmission and the Prediction Model

Jin CHEN[a,1] , Jun WANG[a], Guowei YU[b], Qiqi ZHANG[b], Hongtao ZHANG[b] and Dongzhi ZHAO[b]

[a]*College of Mechatronics Engineering, North University of China,Taiyuan, 030051, China*
[b]*North Huaan Industry Group CO.LTD, Qiqihaer, 161000, China*

Abstract. Wear is an important factor that determines the normal functioning of high-speed transmission. This study aimed to analyze the stress distribution of high-speed transmission using finite element software and the principle of wear reliability. The weak parts where the stress was concentrated were identified. Tests were performed under different conditions using a uniform design. Thus, the major factors influencing the wear prediction model were identified as surface hardness of material, load, and sliding velocity. A mathematical model for wear prediction was then established using the partial least squares method. Experimental verification was performed, and the high precision of the prediction model was confirmed.

Keywords. High-speed transmission, partial least squares method, prediction model, wear

1. Introduction

High-speed transmission mechanism has found wide applications in military and civil fields. One of the most representative applications is the ammunition feed system with a high rate of fire [1]. The high-speed transmission used in the ammunition feed system is a precision, complex product. The reliability of its kinematic accuracy is crucial for the operation of the ammunition feed system. During high-speed firing, the kinematic pair in the transmission undergoes changes in the size and shape of parts due to wear. Friction is the resistance that one surface or object encounters when moving over another. When the contact stress is higher than the yield strength of the material, continuous material loss due to friction occurs [2, 3]. In the study of wear mechanism, Dong Bingwu et al combined with high-speed pendulum bearing testing machine to analyze the wear performance of self-lubricating gasket material [4]. Yang Wenjun et al proposed a mathematical model of mechanical wear condition monitoring based on wear particle feature recognition [5]. Wieczorek Andrzej N et al proposed different models of steel surface wear under two kinds of abrasives based on wear observation [6]. In terms of wear prediction model, Zhao Heming and others analyzed the

---

[1] Corresponding author, Jin Chen, College of Mechatronics Engineering, North University of China, Xueyuan Road District 3, Taiyuan, China; E-mail: chenjinsofia@163.com.

maximum allowable wear of gear transmission mechanism based on ADAMS [7]. Wang Guohui and others established the prediction model of ablation wear of gun barrel based on BP neural network based on genetic algorithm [8]. Chen Yuanling et al established a friction and wear prediction model for the distribution pair of aviation piston pump under the condition of high speed and high pressure [9]. Qin Guohua et al established a neural network prediction model between cutting process parameters and tool wear based on the maximum fusion evaluation index [10]. Most of the previous wear prediction models were derived from the characteristics and wear mechanism of a single mode of wear. For example, Archard [11-13], an English scientist, proposed the wear prediction equation based on the investigation into gear engagement and gear sliding: $W = KSP / P_m$, where W is the wear volume, S is the sliding distance, P is the load imposed, and P_m is the compressive stress encountered by the soft material when flowing.

A chainless transmission was used for the ammunition feed system to ensure the velocity of ammunition feed and the reliability of the ammunition feed mechanism. For example, the rate of fire increases from 850 rounds/min to 6000 rounds/min for a naval gun. At this rate of fire, the speed of relative movement is considerable between the parts, leading to substantial wear of the ammunition feed system. Under some severe situations, jamming of cartridge, reduction in ammunition feed velocity, and suspension of shooting would occur. Therefore, establishing a wear prediction model based on the analysis of the wear mechanism of the high-speed transmission is of high theoretical and practical value.

2. Wear Reliability

Wear reliability involves reliability, friction and wear, material mechanics, mechanical system dynamics, and other disciplines. However, because of the complex mechanical structure, wear reliability research is more difficult. In the study of wear reliability, the cumulative wear and the maximum allowable wear must be determined.

Mechanical wear reliability (P_s) refers to the possibility that the actual wear of the wear pair is within the allowable wear amount in the specified time and under the specified conditions of use. For complex mechanical systems, the reliability can also be expressed as the probability of accomplishing the expected working life. Wear reliability is used to study the reliability of the mechanical system in terms of wear, which is determined by the maximum allowable wear and wear speed. The maximum wear of the system is generally determined by experience or other methods. Different systems and kinematic pairs have different maximum allowable levels of wear. However, the system and the movement of the failure of the components are assessed using the same criteria. It is considered as a failure when the cumulative wear is greater than the maximum allowable wear. For example, in the case of a gear transmission mechanism, the cumulative wear amount of the gear shaft is W_t at time t without considering the wear of the tooth profile, and the maximum allowable wear amount is W_{max} . It is considered as gear transmission failure when $W_t > W_{max}$. Its reliability can be expressed as:

$$R\left(W_{max} \mid t\right) = P\left(W_t < W_{max}\right) \tag{1}$$

Therefore, no matter which kind of kinematic pair is used, the reliability of the damage based on the judgments is consistent. If W_t represents the cumulative wear and W_{max} represents the maximum allowable wear, then:

$$M_W = W_{max} - W_t \tag{2}$$

Where M_W is the state variable at the time of wear, that is, the safety margin.

The wear reliability and failure probability state variables can be expressed as:

$$P_S = P(M_W > 0) \tag{3}$$

$$P_f = P(M_w < 0) \tag{4}$$

For the prediction of the wear reliability of a moving mechanism, it is necessary to determine the maximum allowable wear and cumulative wear.

In studying the wear reliability of a gear shaft, it is assumed that the tooth profile does not wear out in the gear drive. Then, the wear of the gear shaft causes the gear shaft to become thinner, which in turn affects the center distance of the two gears. As the center distance of the gear is increased, it affects the meshing angle. The coincidence degree of the gear will be less than its allowable level when the gear is worn to a certain extent; i.e., when the cumulative wear reaches a certain value. At this point, the relationship between the center distance and the amount of wear can be obtained using ADAMS software simulation. The amount of wear at this time can be defined as the maximum allowable wear.

The wear of components is affected by the load, sliding speed, surface hardness of materials, and other factors. The cumulative wear is the sum of the mass lost in a certain amount of time.

The wear process is divided into three stages: Stage I is called the run-in stage, and the wear rate is high in this stage. After wear and tear, the surface of the material becomes flattened to form a harder oxide layer, and the wear rate gradually decreases. Stage II is called the stabilization phase. After the run-in phase, the wear will enter a long and stable stage. In this stage, the wear rate is almost constant, the wear amount is linearly related to time, and the wear and tear performance are evaluated through this stage. Stage III is the stage of intense wear. In this stage, after the first two stages of wear accumulation, there is a large change in the wear rate and the surface quality deteriorates. In this stage, components will quickly fail. The intense wear stage and the run-in phase are both very short. Thus, in order to simplify the problem, the analysis in this paper will only discuss the stabilization period. In this way, according to the characteristics of stable wear, in the analysis of sportswear reliability, assuming that the wear and tear are proportional to time, W is used to denote the cumulative wear amount in time t, and $\bar{w}$ is the wear rate, the wear life and wear amount can be calculated by the following equation:

$$W = \bar{w}t \tag{5}$$

In summary, according to equation 5, the cumulative wear can be obtained within time t.

From the previous analysis, we can see that the impact of wear factors is random, which makes the amount of wear a random variable. Moreover, as the wear time increases, the randomness also increases. Assuming that the wear level for smooth wear is a random variable, it is expressed by W_0 and its distribution is $f(W_0)$. The cumulative wear of the system is W and the distribution law is $g(W)$, so W can be expressed as:

$$W = g(W) = g\left[f(W_0)\right] \tag{6}$$

If the wear rate $\overline{w}$ is used to express the amount of wear W, W can be expressed as:

$$W = \int_0^t \overline{w}(t)\,dt \tag{7}$$

Where represents wear time.

If the maximum allowable wear of the kinematic pair is expressed by W_{max}, the reliability of the system is:

$$R(W_{max} \mid t) = P(W < W_{max}) \tag{8}$$

The probability of failure is:

$$P_f(W_{max} \mid t) = \int_{W_{max}}^{\infty} g(t)d(W) \tag{9}$$

Its reliability is:

$$R(W_{max} \mid t) = 1 - P_f(W_{max} \mid t)$$

$$= 1 - \int_{W_{max}}^{\infty} g(W)d(W) = \int_{-\infty}^{W_{max}} g(W)d(W) \tag{10}$$

Where $g(W)$ is the probability density function, expressed as:

$$g(W) = \frac{1}{\sigma_W \sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{W - \overline{W}}{\sigma_W}\right)^2\right] \tag{11}$$

Where $\overline{W}$ is the mean of the wear amount and σ_W is the standard deviation of the wear amount.

Thus, according to equations 9 and 10, the reliability of the mechanism to reach the maximum allowable wear is:

$$R\left(W_{\max} \mid t\right) = \int_{-\infty}^{W_{\max}} g\left(W\right) d\left(W\right)$$

$$= \int_{-\infty}^{W_{\max}} \frac{1}{\sigma_W \sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{W - \overline{W}}{\sigma_W}\right)^2\right] d\left(W\right) \tag{12}$$

Where $W_{\max}$ is the maximum allowable wear, $\overline{W}$ represents the mean of the wear, and σ_W denotes the variance of the wear.

Wear reliability (P_S) is defined as the probability of the wear amount of a kinematic mechanism falling within the maximum allowable range of wear in a specific time and under specific use conditions [14, 15]. P_S is determined by the maximum allowable amount of wear and rate of wear.

Ignoring the lubricating effect, the rate of wear is jointly determined by three factors, namely, sliding velocity, material hardness, and load. The judgment criterion for the failure of kinematic mechanism is that the cumulative wear amount is larger than the maximum allowable wear amount.

If W_t is the cumulative wear amount and $W_{\max}$ the maximum allowable wear amount, then

$$M_W = W_{\max} - W_t \tag{13}$$

where M_W is the state variable during wear, that is, safety margin.

Then, the wear reliability is expressed as

$$P_S = P\left(M_W > 0\right) \tag{14}$$

3. Finite Element Simulation of High-speed Kinematic Mechanism

The large module gear in the transmission is made of 30CrNi2MoVA. The modulus of elasticity is $P = 2.1 \times 10^9$ and the Poisson's ratio is $\sigma = 0.25 \sim 0.3$.

Considering that the function of ADAMS software in modeling is relatively weak, and it has a direct interface with 3D modeling software Pro/E, this paper uses Pro/E software to model the gear, and the established gear model is shown in figure 1. After the model is established according to the gear parameters, the model is imported into AMAMS software, and the material and quality information of the gear is defined by AMAMS software. After dynamic simulation, the history curve of gear force and time is obtained, as shown in figure 2. It can be seen from figure 2 that the stress concentration occurs in the tooth profile and root, and the average force is about 1923.548N.
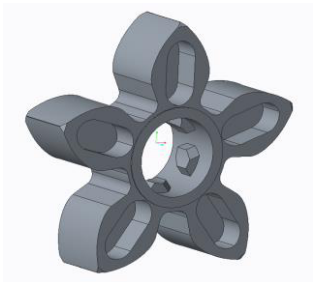
Figure 1. Large module gear built using the Pro/E software.
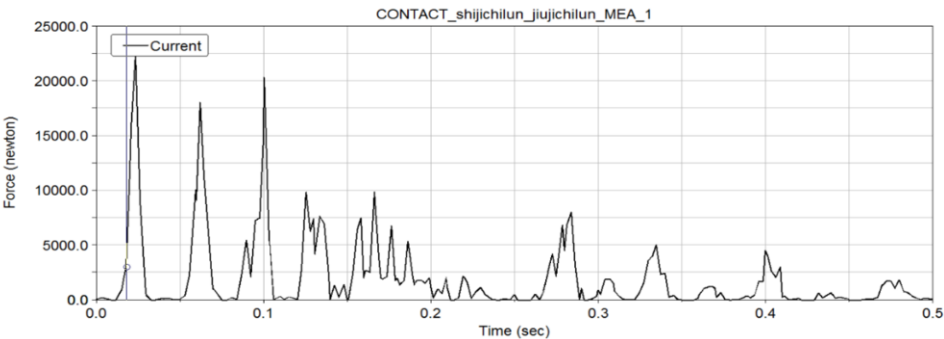
Figure 2. Stress curve of gear over time.

Different parameters of the large module gear are shown in Table 1.

Table 1. Parameters of the large module gear.

Gear parameter	Symbol	Drive gear	Driven gear
Module	m	18	18
Number of teeth	Z	5	5
Profile angle of a gear	A	20°	20°
Addendum coefficient	h_a^*	1.176	1.118
Modificatio coefficient	X	0.3046	0.426

4. Friction and Wear Experiment of High-Speed Kinemate Mechanism

The friction and wear experiments of high-speed kinematic mechanism were performed to obtain the wear amount considering different influence factors.

According to the actual operation of the high-speed transmission, the specimen used for the friction and wear experiment was made of 45# stainless steel. The parameters of thermal treatment of the specimen are shown in Table 2. The counter pair is illustrated in Figure 3.

Table 2. Parameters of thermal treatment of the specimen.

Specimen no.	Material	Thermal treatment
1	45# Stainless steel	Normalization at 600°C, air cooling for 60 min
2	45# Stainless steel	Normalization at 550°C, air cooling for 60 min
3	45# Stainless steel	Normalization at 500°C, air cooling for 60 min
4	45# Stainless steel	Normalization at 450°C, air cooling for 60 min
Counter pair	30CrMnSi	Annealing at 800°C, water cooling
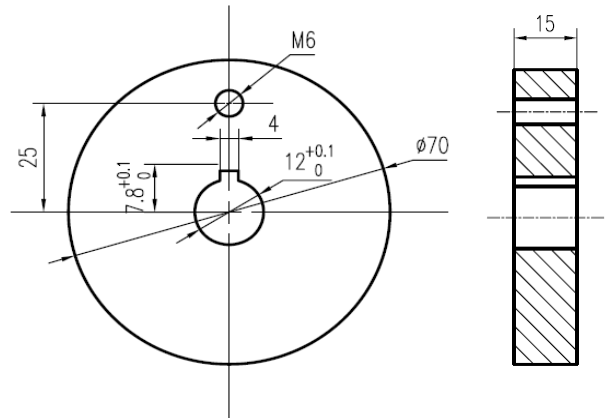
Figure 3. Illustration of the counter pair.

According to the material, contact force, and sliding velocity of the friction pair, the factors considered in the experiment and the levels of each factor were as follows:

Surface hardness of material: 241, 282, 314, and 366 HV

Load: 100–430 N, with 12 levels

Rotational speed: 50–380 r/min, with 12 levels

Time: 30 min

The parameters of the friction and wear experiment are shown in Table 3.

Table 3. Parameters of the friction and wear experiment.

No.	Hardness (HV)	Load (N)	Rotational speed (r/min)
1	241	160	140
2	241	250	260
3	241	340	380
4	282	430	110
5	282	130	230
6	282	220	350
7	314	310	80
8	314	400	200
9	314	100	320
10	366	190	50
11	366	280	170
12	366	370	290

Figure 4. Surface morphology under the load of 130 N, rotational speed 230 r/min, and hardness 282 HV.

The surface morphology of the specimen was observed under the microscope after the experiment. The specimen surface exhibited severe plastic deformation, with the presence of many abrasive specks of dust, which was typical of adhesive wear, as shown in Figure 4.

A large number of grinding cracks and grooves were seen on the specimen surface, which was also typical of abrasive wear, as shown in Figure 5 (load 190 N, rotational speed 50 r/min, and hardness 366 HV).
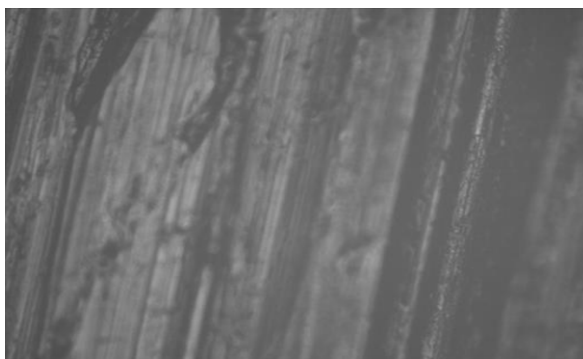
Figure 5. Surface morphology under the load of 400 N, rotational speed of 200 r/min, and hardness of 314 HV.

Therefore, the wear of the high-speed transmission was the combined result of adhesive and abrasive wear.

5. Wear Prediction Model of High-Speed Transmission

The experimental data fluctuated considerably, and the random error was large due to the randomness of the wear process. Therefore, the measurement of wear amount was of a statistical nature. In this study, a uniform design was adopted, and a stepwise regression was conducted on the experimental data. The wear prediction model was built using the partial least squares method.

When building the wear prediction model, x_1, x_2, and x_3 were the three major influence factors of the wear amount, namely, surface hardness of material, load, and sliding velocity.

The quadratic polynomial model built using the uniform design was as follows:

$$y = a_0 + \sum_{i=1}^{3} a_i x_i + \sum_{i=1}^{3} a_{ii} x_i^2 + \sum_{i<j} a_{ii} x_i x_j + \varepsilon \tag{15}$$

where a_0, a_i, a_{ii}, and a_{ij} are coefficients of regression; ε is a random error; and i is the number of influence factors.

After statistical treatment, the quadratic polynomial model based on partial least squares method was derived as follows:

$$y = 15.005778 - 0.024578x_1 + 0.009331x_2 + 0.003675x_3$$

$$-0.000046x_1^2 + 0.0000223x_2^2 + 0.000006x_3^2$$

$$+0.000012x_1x_2 + 0.000005x_1x_3 + 0.000007x_2x_3 \tag{16}$$

The residual sum of squares was 4.5153, indicating that the fitting results satisfied the precision requirement.

Using Eq. (16), several predicted values of the wear amount were calculated and compared against the test values, as shown in Table 4.

Table 4. Comparison of predicted and test values of wear amount.

Variable	Comparison				
	1	2	3	4	5
x_1 (HV)	241	241	282	314	366
x_2 (N)	160	250	430	310	190
x_3 (r/min)	120	260	110	80	50
Test value (mg)	7.77	11.17	18.80	9.80	3.13
Predicted value (mg)	9.89	12.99	14.97	9.59	3.62
Relative error (%)	27.28	16.29	20.37	2.14	15.65

Table 4 shows that the error of the predicted wear amount was small under the aforementioned conditions. This indicated the reliability of the wear prediction model.

6. Conclusion

This novel study analyzed the wear reliability and conducted a finite element simulation of a high-speed transmission. The regions of stress concentration and mean stress values were determined. For the weak parts, friction and wear experiments under different conditions were formulated using the uniform design. The influence factors of the wear prediction model were identified based on the experimental data. Next, the mathematical model for wear prediction was built using the partial least squares method under the three influence factors, surface hardness of material, load, and sliding

velocity. The predicted results were compared with the test results. The prediction of wear amount had a small error and high precision.

In this paper, the wear prediction method of high-speed transmission mechanism of a certain bullet supply system based on stepwise regression analysis has little difference within the range of relative error in the prediction process. Compared with the traditional prediction methods, this kind of method is more efficient and accurate.

Finally, we will also proceed from some aspects, such as redesigning gear parameters, modifying material matching, controlling gear processing quality and improving lubrication conditions. It is believed that this has reference significance for improving the working environment of the transmission mechanism and solving the problem of tooth surface wear. In the future, the establishment method of wear model should be deeply studied in order to establish a more complete and accurate model.

References

[1] Wang P. The guide structure and characteristic analysis of unchained projectile. Nanjing University of Technology. 2009.
[2] Sun WC. The present situation and development trend of abrasive wear research. Technical Innovation and Application. 2008; (02): 71-72.
[3] Guan CH. The mechanism of friction and wear of cylinder liner of Marine diesel engine and the analysis of wear reduction measures. Technology Innovation and Application. 2017; (13): 69-70.
[4] Dong BW, Deng S, Zhang WH. Study on wear mechanism of self-lubricating plain bearing liner. Intelligent Manufacturing. 2020; (04): 50-53.
[5] Yang WJ, Sun YN, Yang YZ, Fan H, Wang GJ. Mechanical wear condition monitoring based on abrasive wear mechanism. Aviation Dynamics Bulletin. 2019; 34 (06): 1246-1252.
[6] Wieczorek A N, Jonczy I, Stankiewicz K, et al. Testing the Wear Mechanisms of the Components of Machines Used in Fossil Energy Resource Extraction. Energies. 2021; 14(8).
[7] Zhao HM, Zhang Y, Zhao YP. Analysis of maximum allowable wear of gear transmission mechanism based on ADAMS. Coal Mining Machinery. 2015; 36(11): 137-139.
[8] Wang GH, Zhang BD, Li XG. Prediction of ablation wear of gun barrel based on BP neural network based on genetic algorithm. Journal of Artillery firing and Control. 2019 Jue; 40 (04): 6-10+15.
[9] Chen YL, Ban CZ, Liu YS, Zhang Y, Zhang Y, Gao XQ. Wear model and life prediction of distribution pair of aviation piston pump. Hydraulic and Pneumatic. 2020; (12): 1-7.
[10] Qin GH, Gao J, Ye HC, Jiang GJ, Huang S, Lai XC. Tool wear prediction based on fusion evaluation index and neural network. Journal of military Industry. 2021; 42 (09): 2013-2023.
[11] Wu YQ. Study and finite element simulation on the wear and friction properties of the besin based friction materials. China University of Geosciences. 2013; (04): 107.
[12] Xu HY. Velocity ratio theory and design principles on solid-liquid pump. Int Conf on Pump and Systems. 1995; (02):527
[13] Wang C. prediction receptivity model analysis for the precision of slide guides based on the wear mode. Tianjin University of Technology. 2015; (01): 64.
[14] Lubas J. Assessment and application of Ti B2 coating in sliding pair under lubrication conditions. Wear. 2012; 296(01): 504-509.
[15] Lubas J. Tribological properties of surface layer with boron in friction pairs. Surface Review and Letters. 2009; 16(05): 767-773.

Optimization of Maritime Search and Rescue Resources Selection Based on Response Threshold Ant Colony Algorithm

Jiahui MAO[1], Yu GUO, Qingqing YANG, Yingying GAO, and Kewei YANG
National University of Defense Technology, College of Systems Engineering, Hunan, China

Abstract. The timeliness and severity of maritime search and rescue (MSAR) determine that the resource selection should be fast and optimized as much as possible. At present, there is no intelligent optimization method to assist decision-making, which is suitable for the actual characteristics of MSAR. In this paper, the optimization problem of MSAR resource selection is abstracted into a multi-objective optimization problem. Considering the needs of actual MSAR resources, the response threshold model is introduced to improve the ant colony algorithm. It can effectively solve the situation that the ordinary optimization algorithm is easy to fall into the local optimal solution and ignore the better resources. The research work of this paper is divided into three parts: model construction, model solution and model verification. Firstly, a multi-objective optimization model with five practical constraints is constructed to minimize the search time and maximize the average utility of resources. Then, the response threshold model considering the actual resource demand is used as the heuristic information in the ant colony algorithm. The stimulus model and threshold model in the response threshold model represent the ability of resources to perform tasks and the threshold of resources to perform tasks respectively, so as to improve the efficiency and speed of the algorithm. Finally, the algorithm is verified and compared through an example. The experimental results show that the average resource utility of this algorithm is 20.6% higher than that of the basic ant colony algorithm, and the MSAR success rate is also improved, which verifies the effectiveness of this method.

Keywords. Maritime search and rescue, resource optimization, ant colony algorithm, response threshold mode

1. Introduction

China is a large marine country with 18000 kilometers of coastline and 3 million square kilometers of sea area. With the development of China's marine industry, marine activities are becoming more and more complex. MSAR accidents occur frequently. In China, there are many MSAR cases every month, resulting in dozens of deaths. Therefore, improving China's MSAR capability has become a very realistic and challenging problem.

At present, relevant research on MSAR methods has been carried out at home and abroad. Among them the representative is the Search and Rescue Manual "international

---
[1] Corresponding Author, Mao Jiahui, National University of Defense Technology, College of Systems Engineering, Hunan, China; E-mail: 18355898796@qq.com.

aviation and MSAR Manual" jointly launched by the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) in 1998 [1]. This manual is summarized and formed on the basis of part I, II and III [2-4] of the search theory. Published by the anti-submarine military operations research group composed of Koopman and his colleagues. Literature [5-8] studies the optimization model and method of rescue ships by using classification analysis, modern decision-making theory and fuzzy mathematics evaluation method. Literature [9-10] studies how to calculate the drift of maritime distress targets with wind and current, determine the search area and range and the optimal search mode.

The research on the resource selection and optimization scheme of MSAR is basically the analysis and evaluation of a single MSAR force. In reality the MSAR behavior is often accompanied by a variety of MSAR forces at the same time. In order to adapt to this change, it is not common to use intelligent optimization algorithm to solve MSAR problems. The only intelligent optimization algorithms used in solving MSAR resources simply apply the basic algorithm framework. For example, common optimization algorithms include genetic algorithm [11-13], DE differential evolution algorithm [14], ant colony algorithm [15-16], etc. They do not consider the actual background needs to design and improve the algorithm, which will lead to insufficient optimization of the final generated resource scheme [17].

Ant colony algorithm is a population intelligent algorithm proposed by Italian scholar Dorigo m et al. [18] in the 1990s. It has strong robustness and is easy to be combined with other optimization algorithms. With the development of the algorithm, ant colony algorithm has been applied to many fields such as job scheduling and path planning [19-22]. However, the common ant colony algorithm does not better consider the resource requirements of MSAR. Although it realizes the solution of the multi-objective optimization model, it is prone to problems such as slow convergence speed, easy to fall into local optimization, long search time and so on.

In recent years, the combination of response threshold model and intelligent optimization algorithm has made it possible to optimize the selection of MSAR resources. The response threshold model is a task distribution model [23-25] proposed to simulate the social division of labor mechanism of insects. According to the perceived information of the task and the internal threshold of the individual undertaking the task. The model determines the probability of the individual response to the task. It reveals the self-organizing labor division mechanism of social insects, and explains the relationship between individual adaptability and system robustness. It can accelerate the convergence speed of ant colony algorithm according to the actual information of the problem and avoid falling into local optimal solution. Wang yingcong [26] and others combined the artificial bee colony algorithm with the response threshold model to prove the effectiveness of the artificial bee colony algorithm based on the stimulus response division mechanism. A.P. Kanakia [27] proposed a task allocation strategy of multi-agent system based on response threshold. Therefore, it is feasible to introduce the response threshold model into the solution of the optimization problem of MSAR resource selection. But it is difficult to better map the elements of the response threshold model with the actual elements of MSAR emergency decision-making. In order to more truly reflect the actual situation of MSAR and better apply the optimization algorithm in MSAR emergency decision-making. This paper innovatively introduces the response threshold model to solve the problems of slow convergence speed and easy to fall into local optimization of ant colony algorithm. An improved ant colony algorithm based on response threshold model is proposed. It can select better resources while optimizing the

objective function, improve the speed of resource selection, and avoid the omission of better resources. To better assist decision makers in making decisions on the selection of MSAR resources selection and improvement in MSAR success rate. The paper is mainly divided into three parts. Firstly, the MSAR resource selection model based on multi-objective optimization is constructed. Then the ant colony improvement algorithm process based on response threshold model is described. Finally an example is compared and analyzed.

2. Problem Analysis and Modeling

2.1. Modeling Assumptions

This paper is conducted under the following assumptions:

- All persons in distress shall be evenly distributed in the search area;
- This paper only considers the situation of aircraft search and ship rescue;
- It is assumed that the time when all MSAR aircraft cover the specified search area is the time of the search phase;
- It is assumed that the performance information of various aircraft under different sea conditions has been known.

2.2. Modeling Establishment

1) Decision variable analysis

MSAR operations are usually carried out in very complex situations. There are many factors affecting MSAR operations and many model input conditions to be considered. Basic information includes: information related to people in distress; information related to the marine environment during MSAR; the impact of the environment on MSAR operations; dangerous situations that MSAR personnel may face.

Relevant parameters and their specific descriptions are shown in Table 1 below:

Table 1. Specific Description of relevant parameters.

Parameters	Description
B	Sea state level during MSAR (level 1-9)
d_m	Distance from military MSAR force to search area (n miles)
d_s	Distance from professional MSAR force to search area (n miles)
d_i^i	Distance from local MSAR force to search area (n miles)
S	Area to be searched $(n\ mile)^2$
N	Number of people in distress (person)
V_i	Maximum speed of resource i (kn)
n_i	Available quantity of resources
cap_j	Aircraft $j's$ search capability $(n\ mile^2/h)$
p_j	Probability of aircraft j finding target
sal_k	Average fishing time of ship k (h)
c_k	The upper limit of the number of people the ship k can carry
h_0	Average maximum waiting time of people in distress

Decision variable: the optimization scheme for the selection of MSAR resources, which should include the description of the types and quantity of resources. Therefore, the mathematical expression of MSAR resource scheme is:

$$X = (x_1, x_2, \ldots, x_M) \tag{1}$$

Where, x_i represents the number of resources in the scheme. If x_i is 0, it means that the MSAR scheme resource i is not involved.

2) Objective function analysis

Objective 1: minimize the search time: the total search time T_s refers to the maximum working time of various resources required to cover the area to be searched. The composition of the total search time is shown in Figure 1.
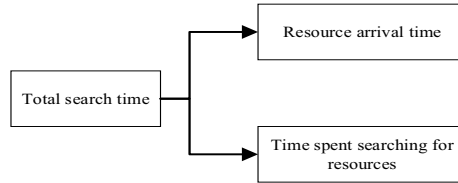
Figure 1. Search time composition.

For aircraft, the time spent on the road needs to be considered. Therefore, the time taken by the aircraft i on the road is t_i

$$t_i = \begin{cases} \frac{d_m}{v_i}, i \text{ belongs to the military search and rescue force} \\ \frac{d_s}{v_i}, i \text{ belongs to the professional search and rescue force} \end{cases} \tag{2}$$

The actual search time of the aircraft i in the total search time is:

$$\overline{t_s} = T_s - t_i \tag{3}$$

The sum of the search area of all aircraft involved in MSAR should be equal to the total area to be searched:

$$\sum_{i=1}^{J}(T_s - t_i) \cdot cap_i \cdot x_i = S \tag{4}$$

$$MIN(T_s) = \frac{S + \sum_{i=1}^{J} t_i cap_i x_i}{\sum_{i=1}^{J} cap_i x_i} \tag{5}$$

Objective 2: maximize the average resource utility: the average resource utility refers to the average value of the utility brought by the resources participating in MSAR. The utility of resources can be measured by the probability of success (POS) [17].

Since the area to be searched is known in this model, assuming that all the people in distress are in the area to be searched, that is $POC = 1$. The probability of discovery refers to the probability that the person in distress is included in the search area of a search subject (the search subject in this paper is an aircraft) and the search subject finds the target.

$$POS = POD \times POC = POD = \sum \frac{S_i}{S} P_i \tag{6}$$

According to formula (6), the average utility of resources is:

$$MAX(E) = \frac{\sum \frac{S_i}{S} P_i}{\sum_{i=1}^{J} x_i} \tag{7}$$

In this paper, the multi-objective problem containing the above two objectives are transformed into a single objective problem, and the model is as follows:

$$MIN\left(w_{T_s} \cdot T_s + w_E / E\right) = w_{T_s} \cdot \frac{S + \sum_{i=1}^{J} t_i cap_i x_i}{\sum_{i=1}^{J} cap_i x_i} + w_E / \frac{\sum \frac{S_i}{S} P_i}{\sum_{i=1}^{J} x_i} \tag{8}$$

Where w_{T_s} and w_E is the weight of target T_s and target E. In the later example, by comparing w_{T_s} and w_E to adjust the parameters, so that the goal of the single objective problem is better.

3)Constants analysis

Due to the limitations of realistic environmental conditions and the attributes of resources. There are certain constraints in the selection and optimization of MSAR resources. The following are the constraints summarized in this paper.

(1) Resource quantity constraint
There is an upper limit on the number of resources available. Therefore, the following constraint should be met in the scheme:

$$0 \leq x_i \leq n_i, n_i \text{ is available quantity for resource } i, i = 1,2,3, \cdots, M \tag{9}$$

(2) Maximum sea state constraint for safe driving of resources
In order to ensure the safety of MSAR resources, it is necessary to ensure that the resources performing MSAR tasks carry out sea operations under the maximum allowable sea conditions.

$$B_i \geq B, B_i \in \{1,2, \cdots, 9\}, i = 1,2, \cdots, M \tag{10}$$

(3) Upper limit of ship accommodation
In order to ensure safe driving, different ships hold different numbers of people.

$$N \leq \sum c_i, i \in \text{involved resources} \tag{11}$$

(4) The time for MSAR resources to reach the specified search area shall not exceed the total MSAR time constraint
Each MSAR resource must arrive at the scene before completing the search task to have the opportunity to participate in the search operation:

$$t_j < T_s \text{ and } t_k < T_r \tag{12}$$

(5) The person in distress was still alive when rescued

The survival level (POL) of the MSAR target is positive. Survival level represents the survivability level of people in distress when they are successfully rescued. It is directly related to MSAR time and sea conditions [28]. Therefore, this paper uses MSAR time and the longest waiting time of MSAR targets to measure the survival level. The expression of POL is as follows reference [29]:

$$POL = 1 - \frac{E_r}{h_0 + \Delta h} \tag{13}$$

3. Model Solving

There are many kinds and quantities of resources involved in MSAR, especially major MSAR. MSAR resource selection is a NP-hard problem. MSAR requires high timeliness, it is difficult to quickly formulate an efficient resource selection scheme through manual and other ordinary methods. Therefore, this paper adopts ant colony algorithm based on response threshold model. In addition to making the intelligent optimization algorithm more in line with the actual needs of MSAR resources. It can also overcome the defects of ordinary ant colony algorithm, such as slow convergence and easy to fall into local optimal solution.

Ant colony algorithm absorbs the foraging behavior characteristics of real ant colonies in nature. It is a distributed multi-agent system with strong robustness. However, when the solution space is complex and multi-modal, it is easy to fall into local extremum and premature. So it is impossible to generate high-quality offshore resource selection schemes.

The response threshold model is closely related to two factors. One is the stimulus intensity s associated with a specific task It can be expressed as the number of encounters, the concentration of chemicals or other quantifiable clues that can be perceived by individuals. The other is the response threshold θ. It describes the internal tendency of individuals to perform tasks. The smaller the threshold, the stronger the tendency. Specifically, when $s \ll \theta$, the response probability is low, and when $s \gg \theta$, the response probability is high. A cluster of corresponding functions meeting the above requirements $T_\theta(s)$ is defined as:

$$T_{\theta_{ij}}(s_j) = \frac{s_j^n}{s_j^n + \theta_{ij}^n} \tag{14}$$

Where n is a constant, which determines the slope of the response threshold curve.

The performance information of resources is introduced into the ant colony algorithm by responding to the stimulus and threshold in the threshold model. It can accelerate the convergence speed of the ant colony algorithm according to the actual information of the problem and avoid falling into the local optimal solution.

In this paper, a single resource performing the task is modeled as an intelligent individual. Through the response threshold model, the response probability of selecting resources to perform the task is determined. According to the resource performance, the more suitable resource is to perform a task, the greater the response probability of the corresponding task. Replace the heuristic information in the ant colony algorithm with the response probability of the resource to the task obtained from the response threshold

model. Update the pheromone and threshold quantity according to the advantages and disadvantages of the scheme obtained by the ant colony algorithm to further update the response probability. The better the scheme is, the greater the pheromone concentration and response probability of the resource selected in the scheme, and the better resources will be given priority in the next iteration. In this way, the resource performance and actual environment requirements can be taken into account in the ant colony algorithm, and the optimal solution can be found faster and better.

The response probability of resources to tasks is determined by two response functions in the response threshold model. One is used to determine the stimulus of resources. Another response function is used to determine the response threshold of the task to resources.

Therefore, this paper adopts ant colony algorithm based on response threshold model to solve the problem of MSAR resources. The specific process is shown in Figure 2.
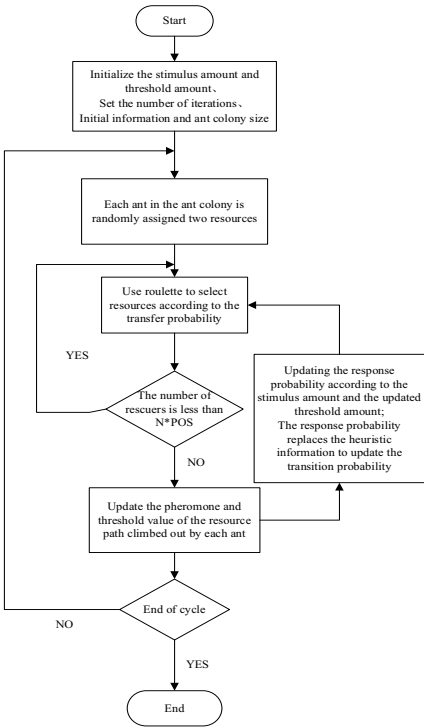
Figure 2. Algorithm flow chart.

3.1. Response Threshold Model for MSAR Resource Designs

Due to the different performance of different types of resources, the efficiency of completing MSAR is also different. Therefore, this paper reflects the performance of different resources through the factors such as the maximum number of ships, the average salvage time of ships, the MSAR sea conditions, the search ability of aircraft, the probability of aircraft discovery and so on.

In order to consider the above factors reflecting the resource performance into the ant colony algorithm. Select the better resources to participate in the MSAR in

combination with the MSAR task. This paper determines the initial response probability of the resources to the MSAR task by the resource performance. In the iterative process, when the resource performance is better and the response threshold of its corresponding task is lower, the response probability is greater and the probability of participating in the task is greater. Therefore, the response threshold model can better meet the resource needs and select better resources.

Using the response threshold model, we need to determine the stimulus s of resources and the response threshold θ of resources to tasks. Through the modeling and analysis of MSAR and the introduction of response threshold model, two functional models need to be determined

1)Stimulus model based on the performance of MSAR resources

The stimulus model reflects the ability of resources to perform tasks. The greater the stimulus, the better the ability of resources to perform tasks. According to equation (14), when the response threshold is certain, the greater the stimulus, the greater the response probability of resources to tasks. Therefore, the higher the probability of selecting better resources, which meets the needs of maritime resource selection.

For different resources (aircraft and ship), due to the different tasks they perform and the different performance parameters they need. The corresponding models will be different when calculating their stimulus.

For ships, the greater the maximum number of people, the shorter the average salvage time, the higher the level of MSAR sea conditions and the shorter the time to reach the area to be searched, the better the resource performance, and the corresponding stimulus s_j should be larger. The greater the stimulation of ship resources j to the task, the greater probability to participate in the rescue action. The stimulation model is shown in formula (15):

$$s_j = \frac{\frac{c_j}{t_j \cdot sal_j \cdot 100} + B_j}{10}, j \in \text{allocable ship} \tag{15}$$

For the aircraft, the stronger its performance search ability, the greater the probability of finding the target, the higher the level of MSAR sea conditions, and the shorter the time to reach the area to be searched. It means the better its performance s_j should be larger. The greater the stimulation of aircraft resource j to the task, the greater probability to participate in the search action. The stimulation model is shown in formula (16):

$$s_j = \frac{\frac{cap_j \cdot P_j}{t_j \cdot 1000} + B_j}{10}, j \in \text{allocable aircraft} \tag{16}$$

2)Threshold quantity model based on cooperation degree of MSAR resources

The resource matching degree refers to the minimum capacity demand or threshold of the task for resources. According to equation (14), when the stimulus amount is certain, the smaller the threshold value the greater the response probability of resources to the task. Therefore, the higher the probability of selecting resources with better performance of tasks, which meets the needs of maritime resource selection.

Coordination of MSAR resources θ_{ij} indicates the probability that resource j also participates when resource i participates in the MSAR mission. In the iterative process, if resource i and resource j appears more times in the optimal solution. The smaller the corresponding θ_{ij} will be, the lower the response threshold of resource i and resource j to the task. Because the number of occurrences of resource i and resource j in the optimal solution means that resource i and resource j cooperate well. Resource i or resource j can better complete the MSAR task, the lower the threshold of participating in the MSAR task should be. Under the ethnic reward and punishment mechanism, the threshold will be reduced when individuals successfully perform the task, the threshold increases when the task is not successfully executed. The threshold value is expressed by the resource matching degree, which can avoid the situation that the solution falls into local optimization due to the prominence of a certain resource.

The threshold quantity model is shown in equation (17):

$$\theta_{ij}^g = \theta_{ij}^g(x) = \theta_{ij}^{g-1} - \frac{ij_{size}^{g-1}}{tabu_{size}^{g-1} \cdot w_\theta} \tag{17}$$

Where ij_{size}^{g-1} represents the number of occurrences of resource i and resource j in the g-1optimal solution. $tabu_{size}^{g-1}$ represents the number of resources in the g-1 generation optimal solution. w_θ is an adjustment parameter that controls the change rate of θ_{ij}^g.

3.2. Ant colony algorithm based on response threshold model

1)Basic idea of ant colony algorithm

The mechanism of ant colony optimization (ACO) is to simulate the behavior of ants in the process of looking for food. When ants are looking for food, they can release a specific pheromone secreted by ants on the their path. So that other ants can detect and affect their behavior within a certain range (tend to choose the path with high pheromone concentration). When more ants walk on a path, the more pheromones left on this path, the higher the pheromone concentration. It makes the following ants more likely to choose this path. In the process of continuous repetition, the path with the highest pheromone concentration is the optimal foraging path [30].

2)Ant colony algorithm based on response threshold model

In this paper, after combining the response threshold model with ant colony algorithm, the relevant formulas and some parameters are as follows. The state transition probability of ant k from node i to node j at time t is shown in (18):

$$p_{ij}^k(t) = \begin{cases} \frac{[\tau_{ij}(t)]^\alpha \cdot [T_{\theta_{ij}}(s_{ij})]^\beta}{\sum_{s \in allowed_k} [\tau_{ij}(t)]^\alpha \cdot [T_{\theta_{ij}}(s_{ij})]^\beta}, j \in \text{Node that the } k \text{ ant select} \\ 0, \text{others} \end{cases} \tag{18}$$

Where $T_{\theta_{ij}}(s_{ij})$ is the response model that acts as heuristic information in ant colony algorithm, τ is pheromone, α is pheromone adjustment coefficient, and β is heuristic information adjustment coefficient.

The pheromone left by the k ant on the path (i, j) is shown in formula (19):

$$\Delta\tau_{ij}^k(t) = \begin{cases} \frac{Q}{L_k}, \text{The } k \text{ ant passes through } (i,j) \text{ in this cycle} \\ \qquad 0, \text{others} \end{cases} \tag{19}$$

The total amount of pheromones left by m ants on the path (i,j) is shown in equation (20):

$$\Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^k \tag{20}$$

Where $\Delta\tau_{ij}$ represents the pheromone increment on the path (i,j) in this cycle, and the initial time is $\Delta\tau_{ij}=0$。 $\Delta\tau_{ij}^k$ represents the amount of information left by the k ant on the path (i,j) in this cycle.

After all ants complete a cycle, they need to update the residual pheromone on the path, that is, the volatilization of pheromone. The pheromone on each path (i,j) is adjusted according to formula (21):

$$\tau_{ij} = (1-\rho)\tau_{ij} + \Delta\tau_{ij} \tag{21}$$

Where ρ is the volatilization coefficient of pheromone.

(1) Select MSAR resources
In ant colony algorithm, there are many ways for ants to choose the next resource. This paper selects the classical roulette method to choose.

The probability of ants selecting the next resource adopts the state transition probability introduced above. Although the probability of selecting each resource is obtained, due to the diversity of ant colony algorithm, it is necessary to ensure that other resources also have the opportunity to be selected. If only resources with high probability are selected, it will become a greedy algorithm. Therefore, choose the way of roulette. First, obtain the probability value of each resource, and sum these probabilities to the total probability value. Then randomly generate a random number between 0 and the total probability range. Then the probability value of each resource is successively subtracted until it is negative to get the next selected resource. Repeat the same operation until the cycle end condition is reached.

(2) Generate MSAR resource scheme
For a MSAR resource selection scheme, all resources can only be accessed once. So the accessed resources need to be stored in the taboo table to avoid repeated access. Among all the accessible resources, we should also consider the performance of the resource, and judge whether the resource can be added to the taboo table according to the state transition probability. The resources of the final taboo table are the resources that ultimately participate in the task, that is, the taboo table is the obtained MSAR resource selection scheme.

4. Experiment

4.1. Experiment description

An accident occurred in a sea area of the Yellow Sea. A merchant ship with 70 people accidentally hit a reef, lost power and was in danger of overturning. The personnel released life-saving equipment and abandoned the ship to actively save themselves. However, due to the bad sea conditions, the drowning personnel had a wide floating range and complex injuries, so it was in urgent need of external rescue. The distance between the place of distress and the nearest professional MSAR center and naval MSAR center is 90 and 120 nautical miles respectively. There are five fishing boats and merchant ships available near the sea area. Moreover, some professional rescue ships and aircraft in the professional MSAR center are performing daily patrol tasks outside, and a small amount of equipment in the naval MSAR center is under maintenance and is not available. It is measured that the area to be searched is 800 (n mile^2), the current sea state is level 4 [31], and the longest waiting time for people under level 4 sea state is 5 hours. The performance information of professional MSAR forces is shown in Table 2, the performance information of military MSAR forces is shown in Table 3, and the performance information of MSAR forces of passing ships is shown in Table 4. The distance between professional MSAR forces and the accident point is 90 (n miles), and the distance between military MSAR forces and the accident point is 120 (n miles).

This paper adopts the ant colony algorithm based on the response threshold model, so the experimental parameters of the basic ant colony algorithm and the parameters of the threshold model will be used in this experiment. Parameter settings are shown in Table 5. The programming language used in this experiment is Java, the code writing tool is MyEclipse 2017 CI, and the running environment is Windows10.

Table 2. Performance information of professional MSAR forces.

Type	Sea state restrictions	Speed (n mile/h)	Capacity	Search ability (n mile^2/h)	Discovery probability	Available quantity	Average rescue time
Helicopter A	Level 4	220	0	100	0.95	2	0
Helicopter B	Level 3	170	0	90	0.7	2	0
Fixed wing aircraft A	Level 4	300	0	130	0.9	3	0
Fixed wing aircraft B	Level 5	620	0	240	0.91	1	0
Huaying rescue boat	Level 4	39	3	0	0	4	0.02
Professional rescue ship	Level 4	27	15	0	0	2	0.06
Fast rescue boat	Level 4	32	7	0	0	3	0.03
Large rescue ship	Level 5	22	12	0	0	1	0.08

Table 3. Performance information of military MSAR forces.

Type	Sea state restrictions	Speed (n mile/h)	Capacity	Search ability (n mile^2/h)	Discovery probability	Available quantity of resources	Average rescue time
Helicopter C	Level 4	280	0	120	0.8	2	0
Transport plane	Level 4	550	0	200	0.95	2	0
Fixed wing aircraft C	Level 3	700	0	270	0.85	0	0
Hospital ship	Level 5	18	40	0	0	1	0.12
Rescue ship	Level 3	35	8	0	0	3	0.01
China high speed rescue ship	Level 5	40	20	0	0	2	0.08

Table 4. Performance information of local MSAR forces.

Type	Sea state restrictions	Speed (n mile/h)	Capacity	Available quantity of resources	Average rescue time	Distance from the ship to the place of distress (n mile)
Fishing boat A	Level 4	12	10	1	0.04	30
Fishing boat B	Level 5	10	9	1	0.01	40
Fishing boat C	Level 5	9	15	1	0.05	80
Merchant ship A	Level 4	32	25	1	0.15	120
Merchant ship B	Level 4	39	10	1	0.10	150

Table 5. Algorithm meaning and value of parameters.

Parameter meaning	Parameter value
Initial population size P_0	33
α(Pheromone adjustment coefficient)	0.6
β (Heuristic information adjustment coefficient)	0.8
ρ(Pheromone Volatilization Coefficient)	0.4
n(Determines the slope of the response threshold curve)	2
w_{T_s}	0.9
w_E	0.1
$\theta_{ij\_}max$(When there is resource i, the maximum response threshold that resource j also participates in)	1
$\theta_{ij\_}min$(When there is resource i, the minimum response threshold that resource j also participates in)	0.1
MAX_GEN (Maximum number of iterations)	1100
τ_{min} (Pheromone minimum)	0.2
τ_{max} (Pheromone maximum)	0.8

4.2. Result Analysis

Substituting the above information into the ant colony algorithm based on the response threshold model and the basic ant colony algorithm can obtain the MSAR resource selection scheme shown in Table 6 and Table 7 respectively.

Figure 3 shows the comparison between ant colony algorithm in this paper and basic ant colony algorithm in iterative objectives. The basic ant colony algorithm can reach the optimal value in about 120 generations. While the ant colony algorithm in this paper has reached a stable state in about 55 generations and converged quickly to the ideal value. Moreover, the final target value of the algorithm in this paper is 1.631, which is better than the target value of 1.636 calculated by the basic ant colony algorithm. Figure 4 shows the comparison between the algorithm in this paper and the basic ant colony algorithm in the average utility of iterative resources. It can be seen from Figure 4 that the average utility value of resources obtained by using the algorithm in this paper is 0.0931. It is better than the average utility value of resources obtained by using the basic ant colony algorithm of 0.0772. Figure 5 and Figure 6 respectively show the comparison of iterative search time and search success rate between the algorithm in this paper and the basic ant colony algorithm. Although the search time of 1.512h obtained by this algorithm is longer than that of 1.041h obtained by the basic ant colony algorithm. The search success rate of 0.931 obtained by this algorithm is higher than that of 0.927 obtained by the basic ant colony algorithm. Moreover, the search time obtained by this algorithm is much shorter than the longest waiting time 5h of people in level 4 sea conditions.

Through the above comparative analysis, it can be seen that the ant colony algorithm in this paper converges faster than the basic ant colony algorithm and is closer to the ideal solution. When the search time meets the MSAR, the average resource utility of the ant colony algorithm based on the response threshold model is 20.6% higher than that of the basic ant colony algorithm.

Table 6. The paper algorithm resource plan display.

Composition of resource scheme		
Professional rescue force	Military MSAR force	Local MSAR force
Helicopter A　x1	Transport plane　x2	Fishing boat B　x1
Fixed wing aircraft A　x1	Hospital ship　x1	
Fixed wing aircraft B　x1	China high speed rescue ship	
Fast rescue boat　x1	x1	
Professional rescue ship　x1		

Table 7. Basic ant colony algorithm resource plan display.

Composition of resource scheme		
Professional rescue force	Military MSAR force	Local MSAR force
Helicopter A　x1	Transport plane　x2	Fishing boat A　x1
Fixed wing aircraft A　x2	Hospital ship　x1	
Fixed wing aircraft B　x1	China high speed rescue ship	Merchant ship A　x1
Huaying rescue boat　x1	x1	
Professional rescue ship　x1		

Figure 3. Target value comparison chart.

Figure 4. Average utility of resources comparison chart.

Figure 5. Search time comparison chart.

Figure 6. Search success rate comparison chart.

5. Conclusion

For the future development of intelligent emergency decision support system. It has important theoretical value and practical guiding significance for improving the timeliness and applicability of the optimization algorithm in MSAR emergency decision-making. In this paper, the optimization problem of MSAR resource selection is abstracted into an operation planning problem. A multi-objective optimization model and a response threshold model considering the actual resource demand are constructed. The response threshold model is combined with ant colony algorithm, and the ant colony algorithm based on the response threshold model is used to solve the model. Through the research of this paper, it effectively solves the problems of slow convergence speed of ordinary optimization algorithm in solving the optimization problem of MSAR resource selection and easy to fall into local optimization and miss better resources. On the premise of obtaining all aspects of information, it can scientifically and effectively generate the optimal resource scheme.

However, the decision-making elements in the actual MSAR are far more complex than those considered in this paper. This paper only makes a preliminary study on the optimization of resource selection. In order to better apply it to practice, there are still many problems to be solved and studied. On the one hand, in the actual situation, the knowledge, experience and preference of decision-makers are very important. In the subsequent research, we can consider adding the preference of decision-makers to realize the combination of man and machine in the solution process of intelligent optimization algorithm, so as to realize a more reasonable solution idea. On the other hand, this paper only uses the ant colony algorithm based on the response threshold model to solve the model. In the subsequent research, it is considered to combine the response threshold model with other algorithms to carry out comparative research.

References

[1] Koopman B O. The Theory of Search. I. Kinematic Bases. Operations Research, 1956, 4(3):324-346.

[2] Koopman B O. The Theory of Search. II. Target Detection. Operations Research, 1956, 4(5):503-531.

[3] Koopman B O. The Theory of Search: III Optimum Distribution of Searching Effort. Operations Research,1957, 5(5):613.

[4] Zhu YZ, Zhao DP, Huang XL. The optimum principle and method for choosing the rescue ship in rescue at sea. Journal of Dalian Maritime University, 1999, 25(4):48-51.

[5] Xue J, Chen ZJ, Papadimitriou E, Wu CZ, P.H.A.J.M. Van Gelder. Influence of environmental factors on human-like decision-making for intelligent ship. Ocean Engineering, 2019, 186:106060.

[6] Xue J, P.H.A.J.M. Van Gelder, Reniers G, Papadimitriou E, Wu CZ. Multi-attribute decision-making method for prioritizing maritime traffic safety influencing factors of autonomous ships' maneuvering decisions using grey and fuzzy theories. Safety Science, 2019, 120:323-340.

[7] Özdamar L, Ekinci E, Küçükyazici B. Emergency logistics planning in natural disasters. Annals of Operations Research, 2004, 129:217-245.

[8] Lyu JF, Zhao HC. Factorial-based particle swarm optimization and its application to maritime moving target search. Control and Decision, 2018, 33(11):1983-1989.

[9] Zhang FG. Study of the optimal search and rescue model of helicopter on sea. System engineering theory and Practice, 2001, 3:87-91.

[10] Srinivas N, Deb K. Multiobjective optimization using nondominated sorting in genetic algorithms. Evolutionary Computation, 1994, 2(3):221-248.

[11] Kalyanmoy D, Samir A, Amrit P. A fast elitist non-dominated sorting genetic algorithm for multi-objective optimization: NSGA-II. International Conference on Parallel Problem Solving from Nature. Springer, 2012.

[12] Hu HQ, Chen JH. Maritime search power optimization research based on genetic algorithm. Ship Electronic Engineering, 2016, 36(12):101-104.

[13] Liu HW, Li X; Gong WY. Rethinking the differential evolution algorithm. Service Oriented Computing and Applications,2020,14(2):79-87.

[14] Zhang GY, Wang HB, Zhao W, Guan ZY, Li PD. Application of improved multi-objective ant colony optimization algorithm in ship weather routing. Journal of Ocean University of China, 2021,20(01):45-55.

[15] He WT, Meng S, Wang JA, Wang L, Pan RR, Gao WD. Weaving scheduling based on an improved ant colony algorithm. Textile Research Journal. 2021;91(5-6):543-554.

[16] Dorigo M, Gambardella L M. Ant colony system: a cooperative learning approach to the traveling salesman problem. IEEE Transactions on Evolutionary Computation, 1997, 1(1):53-66.

[17] Xiong WT, P.H.A.J.M. van Gelder, Yang KW. A decision support method for design and operationalization of search and rescue in maritime emergency. Ocean Engineering, 2020, 207:107399.

[18] Cao Y, Lei L, Fang Y D. Application of ant colony algorithm to job-shop scheduling problem. Advanced Materials Research, 2012, 411:407-410.

[19] Sheng YF. A computational optimization research on ant colony optimization for the traveling salesman problem. Journal of Physics: Conference Series, 2022, 2258:012006.

[20] Wang XH, Zhu YG, Li DY, Zhang G. Underwater target detection based on reinforcement learning and ant colony optimization. Journal of Ocean University of China, 2022,21(2):323-330.

[21] Huang RX, Ning JY, Mei ZH, Fang XD, Yi XM, Gao YY, Hui GH. Study of delivery path optimization solution based on improved ant colony model[J]. Multimedia Tools and Applications, 2021, 80(19):28975-28987.

[22] Yu M. A solution of TSP based on the ant colony algorithm improved by particles swarm optimization. Discrete & Continuous Dynamical Systems-Series S, 2019, 12(4-5):979-987.

[23] Vmdo A, Prac B. The emergence of division of labor in a structured response threshold model. Physica A: Statistical Mechanics and its Applications, 2019, 517:153-162.

[24] Osamu Y, Masashi S, Akinori A, Hiraku N. Verification of mathematical models of response threshold through statistical characterisation of the foraging activity in ant societies. Scientific Reports, 2019, 9(1):8845.

[25] Weidenmüller A, Chen R, Meyer B. Reconsidering response threshold models—short-term response patterns in thermoregulating bumblebees. Behavioral Ecology and Sociobiology, 2019, 73(8):1-13.

[26] Wang YC, Liu JH, Xiao RB. Artifical bee colony algorithm based on stimulus-response labor division[J/OL]. Control and Decision, 2022, 37(4):881-891.

[27] Kanakia, A. P. Response threshold based task allocation in multi-agent systems performing concurrent benefit tasks with limited information. ProQuest Dissertations and Theses Full-text Search Platform, 2015.

[28] Shao MH. Study on the key issues in deployments of the professional rescure vessels for marine traffic safety-taking north China sea as an example. Harbin Engineering University, 2019.

[29] Guo Y. Research on design and application of equipment plan of maritime joint search and rescue. National University of Defense Technology, 2019.

[30] Ren T, Luo TY, Li SX, Xiang S, Xiao HL, Xing LN. Knowledge based ant colony algorithm for cold chain logistics distribution path optimization[J/OL]. Control and Decision, 2022 37(3):545-554.

[31] Yang JK, Han CH, Yang Y, Kong M, Miao QS, Wan FF. A comprehensive analysis on domestic marine environmental data publishing and sharing in China and overseas. Marine Information,2021,36(1):1-10.

Game Analysis of Individual Environmental Law-Abiding from the Perspective of Law and Economics

Lina FA[1]

Shanghai University of Political Science and Law (SHUPL), Shanghai, China

Abstract. The game of environmental issues comes from the restrictions of legal or moral factors on people's environmental needs. In order to effectively solve the problem of environmental pollution and promote enterprises to consider energy conservation and emission reduction based on cost. In this paper, the method of law and economics is used to analyze the change of wood factory game. The introduction of punishment mechanism and reward mechanism proves that only when both parties comply with the law can cost be saved to a greater extent, and when one party violates the law, one party will face serious cost loss. This suggests that we should pay attention to the role of rewards and punishments of environmental legal leverage, and in the subsequent improvement of environmental laws and regulations, we should refine the environmental penalty policy and environmental subsidy policy through environmental taxes, payment of pollution charges and other ways.

Keywords. Game analysis, environmental law-abiding, law and economics

1. Introduction

Environmental pollution is the key to restricting China 's economic and social sustainable development. As a kind of public goods, the environment has the characteristics of multiple consumption and non-exclusive use. In the absence of regulations, enterprises will choose to discharge more pollution into the common environment in order to save personal costs. The externality theory also believes that when the self-cost caused by individual or enterprise behavior is not equal to social cost, and the self-benefit is not equal to social benefit, externality will occur. Environmental pollution reflects a strong negative externality. The cost borne by polluters is far less than the cost borne by society. At this time, rational economic people will not take the initiative to deal with pollution problems. With the improvement of rules, the game of environmental issues has also become an important factor affecting corporate behavior.

In other words, the game of environmental problems starts with people's demand for environmental use. Human beings all have certain demand for environmental use, but due to some moral factors or legal factors, the satisfaction of this kind of demand may be limited. In a same area, for more than a single individual environmental interests, the Law-abiding or illegal own interests have different effects due to the influence of others, which produces a game situation about environmental law-abiding. Through the game

---

[1] Correspondence Author, Lina Fa, Shanghai University of Political Science and Law (SHUPL), Shanghai, China. E-mail: falina12@163.com

analysis of the factors affecting individual environmental compliance, we can accumulate experience for the future improvement direction of environmental law.

2. The Method of Assignment to Explain in Detail

We can use the method of assignment to make a further explain. Assuming there are two timber mills C and D, both of them comply with the relevant environmental laws, then the two mills can each obtain 10 units of product benefits. However, if neither of them do not comply with the relevant environmental laws, the natural resources order will be damaged and the sustainable development of tree resources will be difficult to maintain, and taking labor costs, plant, machine costs in to account, the respective benefits will be -5 each. If the wood mill C obey the relevant provisions of environmental law and mill D disobey, then D can get 15 units of product benefit, after deducting 1 unit of illegal cost, its final benefit will be 14 units of benefit. As for C, they have already lost their original five units of income, at the same time due to the competitive advantage, they also lost 1 unit benefit and finally won the benefit of 4 units, vice versa. The game matrix of timber mills C and D is shown in Table 1:

Table 1. timber mill C and D game matrix.

		timber mill C	
		law-abiding	illegality
timber mill D	law-abiding	A (10, 10)	B (14, 4)
	illegality	C (4, 14)	D (-10, -10)

In this case, the ideal state for both parties are to comply with the law, because if one party fails to comply with the law, the individual will only gain a greater benefit from the other party 's compliance with the law, but if the other party fails to comply with the law, he will face greater losses.

However, it is inevitable that there will be an unfair phenomenon that the law-abiding party suffers losses while the other party violates the law. In this game situation, this no reward and punishment mechanism, the law-abiding situation of the two parties is unstable, and it is impossible to avoid one party breaking the law based on more interests.

3. The Function of Punishment Mechanism of Environmental Rule of Law

When the punishment mechanism of environmental rule of law comes into play and assumed it to be the benefit of 15 units, the result is shown in Table 2.

Table 2. Changes of the punishment mechanism to the game between the two timber mills.

		timber mill C	
		law-abiding	illegality
timber mill D	law-abiding	A (10, 10)	B (4, -1)
	illegality	C (-1, 4)	D (-25, -25)

It can be seen from the comparison of the two tables above, the situation that both parties abide by the law is still the most ideal. In the case of one party abide by the law and the other party violate the law, the income of the illegal party will be less than that of his compliance with the law, even if both mills break the law, the loss of the two mills will be huge, and the cost of their violation will rise sharply. This mutually loss-losing situation makes C and D factories bring more cautious when they want to violate the relevant provisions of environmental laws. and based on maximizing benefits, the two companies will choose to comply with the law.

In this case, it is obvious that the introduction of punishment mechanism in the environmental rule of law makes it very effective to increase the cost of violation. Therefore, in the environmental rule of law, when the individuals consider whether to violate the law or not, the illegal cost becomes a major factor to consider. If the cost of illegal interests is high and the risk of illegal benefits is large, the individuals are less likely to be environmentally illegal due to the instinct of seeking benefits and avoiding harm. In other words, enterprises in making environmental pollution behavior will measure whether the benefits will exceed the cost due to violations of the law.

Furthermore, the introduction of punishment mechanism forces high-energy-consuming enterprises with weak competitiveness to carry out industrial upgrading. In the case of increased illegal costs, in order to avoid the risk of being eliminated by the market, high-energy-consuming enterprises will use clean technology and clean energy for greater cost savings and high efficiency. Using technological innovation to reduce energy consumption and product prices in order to expand the market and obtain additional economic benefits.

Therefore which also enlightens us to clarify the punishment responsibility of environmental pollution behavior and refine the legal responsibility. It is necessary to avoid too light punishment responsibility to prevent enterprises from taking risks for greater benefits, and to avoid excessive responsibility, affect the enthusiasm of enterprises.

4. The Function of Punishment Mechanism and Reward Mechanism

If the leverage effect of environmental rule of law is not only the punishment mechanism, but also take the reward mechanism into account, then the game between two economic individuals will produce a huge change. If the reward mechanism is the benefit of 5 units, the benefit comparison is shown in Table 3:

Table 3. Two timber mills added two kinds of mechanism game matrix.

		timber mill C	
		law-abiding	illegality
timber mill D	law-abiding	A (15, 15)	B (9, -1)
	illegality	C (-1, 9)	D (-25, -25)

As is shown in the figure, after adding the two punishment and reward mechanisms of environmental law, the timber mills will have a greater risk of illegal additional benefits. If both individuals choose to break the law, both companies will suffer heavy losses. If one company breaks the law and another company abides by the law, the law-abiding party will gain more benefits than the illegal behavior due to the incentive mechanism. In this case, environmental violations take greater risks while the profit

income is small, and the possibility of people to choose to break the law will be greatly reduced.

Through the analysis and summary of the above table, we also see the important role of the punishment and reward mechanism in the environmental rule of law. The correct application of the punishment and reward mechanism and the use of economic means to improve the laws and rules are more conducive to regulating the behavior of enterprises. The life of the law lies in the implementation. We should truly apply the punishment and reward mechanism to the implementation of the law to play a joint role in Standardizing the behavior of enterprises.

On the one hand, through strict environmental regulations and legal liability, enterprises are encouraged to take a number of measures to reduce pollution, such as the acquisition of sewage equipment, reduction of production to meet environmental standards, payment of sewage charges and environmental taxes and introduction of environmental protection technologies. Although it will increase the production costs and reduce the profits of enterprises to some extent, in the long run, it is conducive to promoting the closure and transformation of energy-intensive enterprises, improving the local environment, making more green enterprises have more market space and improving their competitiveness.

On the other hand, the incentive mechanism is used to give certain support and incentives to clean industries and green environmental protection industries in terms of fiscal policies and industrial policies, so as to promote the development of environmental protection enterprises, thus indirectly leading to the decline of the proportion of pollution industries and forming the relative transfer of pollution industries.

5. Conclusion

Therefore, in the process of promoting the environmental rule of law, we should pay attention to the regulatory role of rewards and punishments of the environmental legal lever, and also, we should discuss and study the policies of environmental fines and environmental subsidies. And play the important role of market-driven environmental policies such as emission taxes and tradeable emission rights. Achieve emission reduction targets at lower cost through incentive market mechanisms on the basis of controlling total pollution emissions. The incentive environmental policy is combined with the mandatory environmental policy, and the environmental reward and punishment mechanism is refined to make the interest individual more inclined to conservative choice when considering the risk of environmental violations.

References

[1] Zheng L, Qian Y H and Le J B. Environment knowledge, law-abiding consciousness and risk perception influencing environmental behavior. E3S Web of Conferences. 2020; Volume 165:2-32.

[2] Michael W and Anthony RTE. Law, economics and the environment. Managerial Auditing Journal. 2004;19(6):760-773.

[3] Faure M. The export of ecological civilization: reflections from law and economics and law and development. Sustainability. 2020;12(24):10409-10409.

[4] Huang Y and Wang J and Yang S. Research and analysis on how to improve the awareness of environmental protection. IOP Conference Series: Earth and Environmental Science. 2019;252(3):32-35.

[5] Hong W D. Why does environmental compliance cost more than penalty? Frontiers of Environmental Science & Engineering in China. 2007;1(4):434-442.

[6] Tang J M and Tang D. The linkage effects of corporate environmental performance and economic performance. International Journal of Environment Research. 2021;3(3):36-79.

Ecological Risk Assessment of Antibiotics Distribution Characteristics on Urban Lakes of Xi'an-China

Min WANG[a,b1], Lei TIAN[a,b], Jingxin SUN[a,b], Yutong ZHANG[a,b], Wen CHENG[a,b], Lin WAN[b], Chen HUANG [a,b] and Yong WANG[b]

[a]*State Key Laboratory of Eco-hydraulics in Northwest Arid Region, Xi'an University of Technology, Xi'an 710048, China*
[b]*Institute of Water Resources and Hydro-Electric Engineering, Xi'an University of Technology, Xi' an 710048, China*

Abstract. The solid phase extraction-ultra high performance liquid chromatography-tandem mass spectrometry was used to detect and analyze antibiotics in the water of four urban lakes in Xi'an—Hancheng Lake, Xingqing Lake, Nanhu Lake and Tao Huatan. A total of 15 types of antibiotics were detected in the water samples at a concentration between ND-280.16ng/L, of which Sulfamethoxazole (SMX), Sulfamonomethoxine (SMM), Ofloxacin (OFX), dehydrated red Erythromycin (ETM)and Roxithromycin (RTM) are the main types of antibiotics in four lakes in Xi'an; The ecological risk of antibiotics in four lakes was evaluated by Risk Quotients method (RQ). The results showed that the five antibiotics in Tao Huatan were at high risk level. Three antibiotics were at high risk level in Hancheng Lake and Xingqing Lake, and two antibiotics were at high risk level in Nanhu Lake.

Keywords. Urban lakes, antibiotics; pollution, ecological risk assessment

1. Introduction

As a new type of pollutant, antibiotics have been detected in many rivers, sewage treatment plants and even drinking water in our country. Although the detected concentration of antibiotics in the water environment is generally very low [1], due to its direct toxic effect on aquatic organisms and the induction of drug-resistant bacteria or genes at low concentrations, antibiotics increase the potential health and ecological risks through the food chain [2]. Therefore, it is of great value to study the distribution of antibiotics and ecological risks in water.

---

[1] Corresponding Author, Min Wang, 1State Key Laboratory of Eco-hydraulics in Northwest Arid Region, Xi'an University of Technology, Xi'an 710048, China; E-mail: wangmin@xaut.edu.cn.

2. Literature Review

In recent years, the study of emerging contaminants in water is a hot issue. Many scholars have studied the pollution characteristics of antibiotics in urban lakes. Ding [3] conducted research on 5 urban lakes in Nanchang City, and found that the maximum detection limits of quinolones and macrolide antibiotics were 97.2ng/L and 98.4ng/L respectively; Wang [4] took Yuehu Lake (Ning Bo City) as the research object and found that the maximum detection limit of ampicillin (AMS) was 382.0ng/L, and the risk quotients of 5 antibiotics was at a high risk (RQ>1). Due to the differences in water environmental conditions of lakes in various cities, the pollutant characteristics of these lakes are also significantly different, so we should carry out research according to the actual situation of each lake.

3. Study Objectives

Urban lakes were mostly in static, closed or semi-closed state, with poor self-purification capacity [5]. In addition, the impact of water internal life, industrial wastewater discharge and production and life of surrounding residents, resulting in an increase in the content of pollutants in urban lakes and water eutrophication. Therefore, urban lake water pollution has become an important part of the current environmental pollution.

Based on these situations, the study selected four typical lakes in Xi'an: Hancheng Lake, Xingqing Lake, Nanhu Lake, and Tao Huatan, and took the lake surface water as the research object to analyze the types and distribution characteristics of antibiotics in the lakes and their correlation with water quality indicators and evaluate the ecological risks of antibiotics to provide references for ensuring the ecological safety of urban lakes.

4. Materials and Methods

4.1. Study Description

This research involves four typical urban lakes in Xi'an which located in the four directions of the city. Each lake has a different history, so it is fully representative and can represent the lake water of Xi'an universal characteristics.

Hancheng Lake was completed in April 1971, with a total length of 6.27 km and a total capacity of 137 m3. When filled with water, it forms a lake surface of 0.57 km^2. The lake flows into the Weihe River from south to north. The water supply comes from the Fenhe River. The designed flow of diversion is 1.7m^3/s and the residence time is about 9.3d. Before the urban river reconstructed in 2009, Hancheng Lake was the main sewage outlet for urban sewage. After the urban river reconstructed, a reinforced concrete box culvert was designed at the bottom of the pool to undertake the urban sewage and rainwater drainage tasks of Xingqing Lake, the moat, the old city and the northwestern suburbs [7].

Xingqing Lake, as the largest water area in Xi'an for a long time, built in 1975. It is composed of the Great Lake, East Lake, West Lake, North Lake, South Lake and the channel around the lake, inlet and outlet canals, and two sedimentation tanks in the east and west. The average water depth is 1.6m. It is a flood control buffer reservoir in the eastern suburbs in Xi'an.

Nanhu Lake, also known as Qujiang Lake is a famous sight, built in July 2008. The water of the lake is drawn from the Heihe River. The total area of the lake is 33.37 Hectares. It is composed of the upper lake in the south and the lower lake in the north. The average water depth is 1.68m, and the water quality is Grade IV according to Environmental quality standards for surface water (GB 3838-2002) [8].

Tao Huatan is located at the widest part of the lower reaches of the Chanhe River, with a water area of 40.5 hectares, 1.2 km long from north to south, 660m wide from east to west, and an average water depth is 2.8m. There are two pollution sources near Tao Huatan, one is the sewage discharge from the 3rd sewage treatment plant in Xi'an, and the other is the wastewater discharge from the steel processing plant. The overall water quality of Tao Huatan is between Grade III ~V [6, 8].

4.2. Sample Collection and Pretreatment

In May 2019, the water inlets, lake centers and water outlets of Xingqing Lake, Tao Huatan, Hancheng Lake and Nanhu Lake in Xi'an were sampled, the position of sampling points is shown in Figure 1. The weather was clear in the sampling period. 5L water samples were collected below 50cm of the surface. Store it in a brown glass sampling
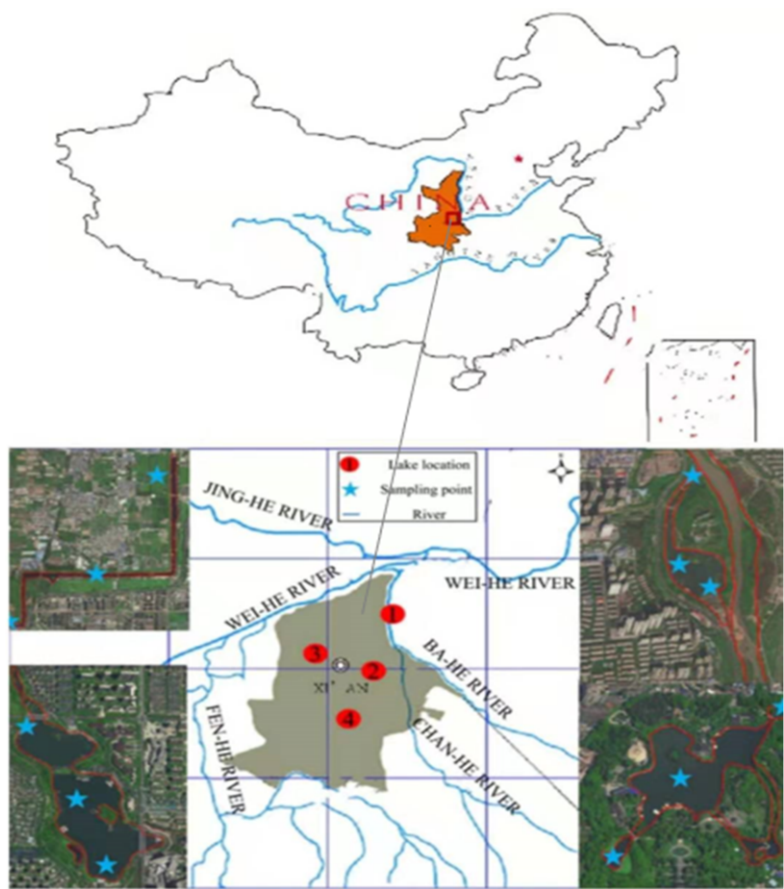
Figure 1. Distribution of sampling points.

bottle, transport it back to the laboratory, and keep it sealed at 4°C, in accordance with the *Water Quality Sampling --Technical Regulation of the Preservation and Handling of Samples* (HJ 493-2009) [9].

4.2.1. Sample Analysis. After the sample was pretreated, the activated Oasis HLB column was used to extract and concentrate the antibiotics in the water sample, and then the antibiotics are determined by high performance liquid chromatography-tandem mass spectrometry (Agilent 1200 HPLC, Agilent 6460 MS). The chromatographic column was a C18 column. In the positive mode, mobile phase A was buffer (0.2% formic acid and 2 mM ammonium acetate), and mobile phase B was acetonitrile. In negative mode, mobile phase A was MilliQ water and mobile phase B was acetonitrile. For detailed extraction and detection steps, refer to the analysis method of Meng [10, 11].

4.2.2. Ecological Assessment. The ecological environmental risks of antibiotics were evaluated by Risk Quotients (RQ). According to European Union technical guidance documents and European Chemicals Agency guidelines, RQ can be calculated from Measured Environmental Concentration (MEC) and Predicted No Effect Concentration (PN EC). Its formula is:

$$RQ_i = MEC_i/PNEC_i \tag{1}$$

In the formula:
RQi--Risk quotients of the i antibiotic
MECi--Measured drug concentration of the i antibiotic in the water environment, ng/L
PNECi--Predicted ineffective concentration of species i (pollutant), ng/L
According to the RQ classification method proposed by Hernado [12] to characterize the different degrees of ecological risks, RQ can be divided into three categories: high risk (RQ>1), medium risk (0.1<RQ<1), and low risk (RQ<0.1).
The PNCE value of antibiotics in the water is obtained by consulting the literature, or by collecting acute or chronic toxicological experimental data (half effective concentration, Effective Concentration 50, EC_{50}; half lethal concentration, Lethal Concentration, LC_{50}; minimum invalid concentration, No Observed Effective Concentration, NOEC, etc.) and assessment factors (Assessment Facters, AF), the calculation formula is:

$$PNEC = LC_{50}/AF \quad \text{or} \quad EC_{50}/AF \tag{2}$$

In the formula:
LC_{50}--the half lethal concentration (ng/L);
EC_{50}--the half effective concentration (ng/L), both LC_{50} and EC_{50} can be obtained through relevant literature;
AF--stands for safety factor or evaluation factor
The classification of the safety factor is: the maximum non-observation effect concentration of the simulated ecosystem, AF=1~5; the maximum non-observation effect concentration of three trophic organisms of three species, AF=10; the maximum non-observation effect concentration of two trophic organisms Observation effect

concentration, AF=50; the maximum non-observation effect concentration of a trophic organism AF=100; the half effective concentration of a species of three trophic levels AF=1 000. According to the toxicology data in the CETOX database, the acute and chronic evaluation factors in this study are taken as 1000 or 100.

4.2.3. Analysis of Physiological Stress of Antibiotics on Algae. As a sensitive organism to antibiotic toxicity, algae was often used as target organisms for antibiotic toxicology research. At present, some research results mainly focus on the physiological and biochemical reactions of different kinds of algae under the stress of high concentration (mg/L) of antibiotics. Some people have studied the effect of antibiotics on the activity of SOD enzyme in cluster scaphoid algae [19]; Some scholars studied the changes of CAT, SOD activities and MDA content in Microcystis and Chlorella cells under the combined stress of single and multiple antibiotics [20]. However, in the real environment, the content of antibiotics in water is very small. Therefore, it is of great practical significance to study the effect of low concentration of antibiotics on the physiological process of algae in water. In this study, according to the detection of antibiotics, typical antibiotics were selected to investigate the stress effects of different concentrations of antibiotics on the growth of Microcystis aeruginosa and Chlorella. After the algae was cultured, the algae in logarithmic growth phase was selected for experiments, and the density of algae cell and the content of Chlorophyll a were analyzed after 24 h and 48 h of stress. Calculate the density of the algae by using the characterization value OD of the ultraviolet absorbance of Microcystis aeruginosa at 675nm and Chlorella at 680nm.The calculation formula is:

Density of Microcystis aeruginosa:

$$(\frac{10^9 \text{cells}}{L}) = 23.851 \times OD675 \tag{3}$$

Density of Chlorella:

$$(\frac{10^9 \text{cells}}{L}) = 20.0 \times OD680 \tag{4}$$

5. Results and Analysis

5.1. Detected Types and Concentrations of Antibiotics in Lake Water in Xi'an

Through sampling and analysis of four lakes, a total of 15 antibiotics in 5 categories were detected. The detected concentrations and detection rates of antibiotics are shown in Table 1. Among the 15 antibiotics detected, the detection rate of 7 antibiotics reached 100%. The antibiotics with the highest detected concentration were Sulfamethoxazole 132.27ng/L, Sulfamonomethoxine175.06ng/L, Ofloxacin280.16ng/L, Anhydroerythromycin 164.84ng/L, Roxithromycin169.59ng/L. In terms of detection rate and detection concentration, Sulfamethoxazole, Sulfamethoxazole, Ofloxacin, Erythromycin Dehydrate and Roxithromycinare the main types of antibiotics in Xi'an urban lakes.

Table 1. The overall detection concentration and detection rate of antibiotics in urban lakes in Xi'an.

		Range (ng/L)	Freq (%)
SAs	SDZ	ND3.99	41.6
	SMZ	1.0569.25	100
	SMX	ND	75
	SMM	ND175.06	83.3
	SPD	ND	25
QNs	CFX	ND10.26	33.3
	EFX	ND4.16	25
	NFX	ND60.31	66.6
	OFX	9.16280.16	100
MLs	CTM	3.2116.58	100
	ETM	7.62164.84	100
	RTM	2.56169.59	100
OTCs	TC	ND	25
Others	LCM	2.73	100
	TMP	0.5315.32	100

ND: None detected

Due to the environmental differences of each lake, the types and content of antibiotics in these lakes are different. The main types of antibiotics contained in the four lakes: Ofloxacin and Erythromycin Dehydrate in Hancheng Lake, Ofloxacin and Erythromycin Dehydrate in Xingqing Lake, Sulfamonomethoxine in Nanhu Lake, Tao Huatan for Sulfamethoxazole, Ofloxacin and roxithromycin. Antibiotic concentrations detected in four urban lakes are shown in Figure 2, The average total concentrations of 15 antibiotics were: Tao Huatan (45.23ng/L)>Hancheng Lake (27.13ng/L)>Xingqing Lake (17.14ng/L)>Nanhu Lake (15.90 ng/L).
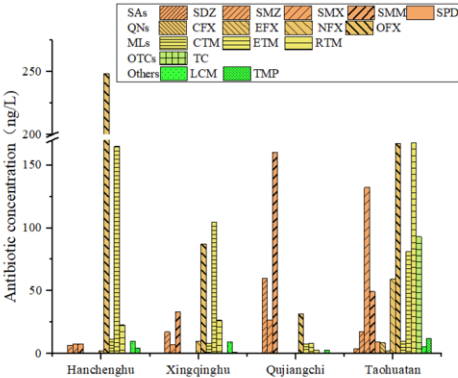
Figure 2. Comparison of antibiotic concentrations in urban lakes in Xi'an.

Studies have shown that the pollution of antibiotics in urban lakes is relatively common. We horizontally compared the content of main antibiotics in lakes in Xi'an with those in other cities in China. The results are shown in Table 2.The result shows that the detected concentration of Sulfamethoxazole (SMX) in the four lakes in Xi'an is ND-132.27ng/L, which is slightly higher than the Songhua River, and is on the same order of magnitude as Yuehu Lake (Ning Bo City), Weihe River, Pearl River and Chaohu Lake, far less than Baiyangdian Lake(ND-940ng/L)and Huangpu River (2.2-764.9ng/L); Sulfamonomethoxine (SMM) is the highest in Nanhu Lake, reaching 175.06ng/L, which is slightly lower than the highest value in Yuehu Lake (Ning Bo City); the detected concentration of Ofloxacin (OFX) in four lakes in Xi'an is 9.16 -280.16ng/L, which is on

the same order of magnitude as Nanhu Lake (Wu Han City), and is higher than the detection level of Weihe River, Pearl River, Chaohu Lake, Songhua River, Baiyangdian Lake and Huangpu River; The detected concentration of Roxithromycin(RTM) in four lakes in Xi'an is 2.56-169.59ng/L, which is on the same order of magnitude as that of Weihe River, Pearl River, Songhua River, Baiyangdian Lake and Huangpu River; The detected concentration of Erythromycin Dehydrate (ETM) in four lakes in Xi'an was 7.62-164.84 ng/L, which was far lower than the maximum detected concentration of 636 ng/L in the Pearl River. In summary, compared with other lakes, with the exception of Sulfamonomethoxine (SMM) and Ofloxacin (OFX), the detected concentrations of other antibiotics in the water of four lakes in Xi'an are at a moderate level. The detected concentrations of Sulfamonomethoxine (SMM) and Ofloxacin (OFX) were higher than other lakes.

Table 2. Concentration distribution of antibiotics in different water in China.

Lake	SMX (ng/L)	SMM (ng/L)	OFX (ng/L)	RTM (ng/L)	ETM (ng/L)
Hancheng Lake	3.15-8.06	5.13-9.96	100.25-280.16	16.28-25.64	59.64-164.84
Xingqing Lake	ND-6.03	ND-40.15	29.16-90.13	19.65-30.18	59.98-104.89
Qujiang Lake	ND-27.10	ND-175.06	9.16-45.06	2.56-3.21	7.62-9.06
Tao Huatan	ND-132.27	30.02-51.48	108.34-167.27	554.10-169.59	68.12-88.05
Ningbo Yuehu Lake [5]	ND-104.0	31.50-219.0	-	-	-
Wuhan Nanhu Lake [12]	-	-	16.82-73.15	-	-
Weihe River [13]	7.6-114.46	ND-14.74	ND-71.99	1.57-59.49	-
Pearl River [14]	111-193	-	53-108	13-169	423-636
Chaohu River [15]	ND-171.6	-	ND-50.6	-	-
Songhua River [16]	2.1-73.1	-	0.01-1.80	0.2-11.5	-
Baiyangdian Lake [17]	ND-940	ND-23.1	0.38-32.6	ND-155	ND-121
Huangpu River [18]	2.2-764.9	-	ND-28.5	0.2-2.2	-

ND: None detected;-: Not detected

5.2. The Relationship Between the Detected Concentration of Antibiotics and the Main Water Quality Indicators

In order to evaluate the potential ecological risks of antibiotics in urban lakes in Xi'an, the study selected the five antibiotics with the highest concentrations and calculated their risk quotients (RQ). The calculation results are shown in Table 3.

Table 3. Toxicology data and ecological risk assessment results of antibiotics.

Antibiotic	Specspecies	Toxicity	AF	PNEC (ng/L)
SMX	S.leopoliesis	acute	1000	27
SMM	-	-	-	1720000
OFX	P.subcapitata	chronic	100	11.3
RTM	P.subcapitata	chronic	100	100
ETM	P.subcapitata	chronic	100	20

-: No data

According to the evaluation result of antibiotic risk quotients value (Table 3), the RQ value of SMX in Tao Huatan is 4.9, which is at a high risk level. The RQ value of SMX in lake water in the other three cities is between 0.1-1. All are at a medium risk level; for SMM, its RQ values in the four lakes are all at high risk; OFX's RQ in the four lakes are all relatively high, exceeding 1, indicating the potential ecological risk of OFX in the four lakes are all at high risk. And the potential ecological risk of OFX in the water of Hancheng Lake is the highest, reached 24.79; in addition, the RQ of RTM of the four

lakes is relatively small, only the RQ value of Tao Huatan is more than 1, which is at high risk. The RQ of the RTM in the other three lakes is at a medium risk level; the RQ of the ETM in Nanhu Lake (0.1-1)is out of the medium risk, but that in the other three lakes is more than 1, are all at a high risk level.

In summary, the types, content and potential ecological risk levels of antibiotics in the four lakes in Xi'an are different. OFX and SMM in the four lakes are high-risk (RQ>1); ETM in the water of Hancheng Lake, Xingqing Lake and Tao Huatan is a high-risk state (RQ>1); The RQ values of SMX and RTM in the water of the four lakes are relatively low, except Tao Huatan which is in a high-risk state (RQ>1). Tao Huatan is also the only one of the four lakes, which all the four antibiotics are in high-risk. Three antibiotics in the water of Hancheng Lake and Xingqing Lake are at high risk.

The antibiotics OFX and ETM with the highest ecological risk levels belong to fluoroquinolones and macrolide antibiotics. These two types of antibiotics are mostly used in human medicine and livestock and poultry breeding, which have higher detection concentrations. The potential ecological risks of the five main antibiotics in Tao Huatan are relatively high, which perhaps because the water in Tao Huatan is mainly affected by the effluent from the sewage treatment plant.

5.3. Stress Effects of Typical Antibiotics on Algae Growth

According to the detected concentration, detected rate and risk of antibiotics in four lakes in Xi'an, three antibiotics (SMX, ETM and OFX) were selected. Taking Chlorella as the research objects, the changes of algae cell density under the stress of three kinds of antibiotics were analyzed and studied to evaluate the effect of antibiotics on the physiological activities of Chlorella.

5.3.1. The Effect of Antibiotics on Algae Cell Density. It can be seen from Figure 3 that under the stress of different concentrations of antibiotics, the overall trend of Microcystis aeruginosa cell density was: with the increase of antibiotic concentration, the cell density decreased, but the change of cell density under different antibiotics and stress time was slightly different.
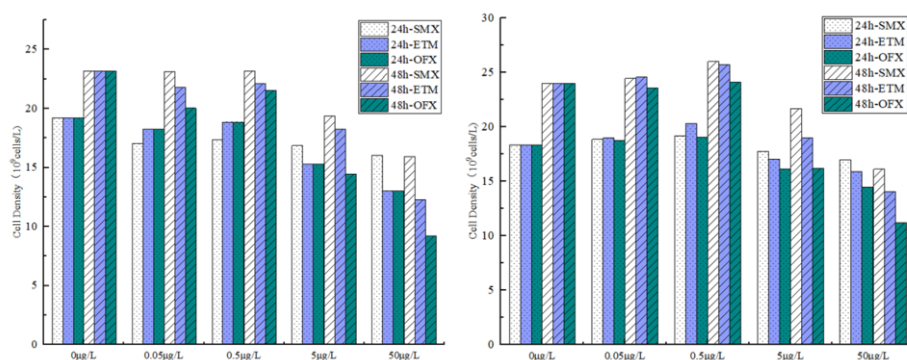
a. The effect of antibiotics on the cell density of Microcystis aeruginosa
b. The effect of Antibiotics on cell density of Chlorella
Figure 3. The effect of antibiotics on the cell density of algae cell.

The effect of Sulfamethoxazole on the cell density of Microcystis aeruginosa and Chlorella showed that at low concentrations (concentration<0.5μg/L), the cell density did not change significantly (compared with the control group); the cell density decreased significantly (concentration is >5μg/L), and the degree of decrease becomes more obvious with time going by (compared with the control group). When the concentration of Sulfamethoxazole was 50μg/L, the cell density of Microcystis aeruginosa decreased by about 18% in 24 hours and 31% in 48 hours, Chlorella cell density decreased by about 16% in 24 hours and 33% in 48 hours (compared with the control group). It can be seen that with the prolongation of stress time, the physiological activities of Microcystis aeruginosa and Chlorella were inhibited more significantly, and the cell proliferation rate was significantly reduced.

At different concentrations of Dehydrated Erythromycin, the cell density Microcystis aeruginosa and Chlorella showed a small increase first and then a rapid decrease trend. When the concentration of Dehydrated Erythromycin was 5μg/L and 50μg/L, the cell density decreased by 20% and 32% within 24 hours, respectively; with the extension of stress time, it decreased more significantly within 48 hours, by 21% and 47% respectively (compared with the control group). When the concentration of Dehydrated Erythromycin was 0.5μg/L, the cell density of Chlorella was the highest. When the concentration of Dehydrated Erythromycin was 5μg/L and 50μg/L, the cell density decreased by 7% and 32% during the 24 hour growth cycle; during the 48 hour growth cycle, it decreased by 21%、42%，respectively (compared with the control group).

The stress response of Ofloxacin to Microcystis aeruginosa is similar to the previous two antibiotics. When the concentration was low (concentration <0.5μg/L), the cell density of Microcystis aeruginosa increased slightly; the algae cell density decreased rapidly (antibiotic concentration >5μg/L). The effect of Ofloxacin on the cell density of Chlorella at different concentrations is shown in Figure 3-b. When the reaction time was 24h (stress concentration ≥5μg/L), the cell density decreased significantly, by 12% and 21% respectively; when the reaction time was 48h, and the stress concentration was 5μg/L and 50μg/L, the cell density decreased by 32% and 53%, respectively.

From the change of algae cell concentration under the stress of three different concentrations of antibiotics, it can be seen that the cell concentration increased under the condition of low concentration of antibiotics, and the cell concentration was inhibited under the condition of high concentration of antibiotics, which is consistent with the Hornesis effect [21]. With the increase of antibiotic concentration, the inhibition degree of algae growth also increased, which perhaps because that in the low concentration (0-0.5μg/L) treatment group, the number of algae cells increased slightly with the increase of reaction time, but the tolerance of single algae cell to antibiotics was relatively weak. Although algae cells could still divide, their divisive speed was still lower than that of the control group. When the concentration of antibiotics was greater than 5μg/L, the number of algae cells decreased significantly, which may have exceeded the tolerance limit of algae cells to antibiotics, the normal physiological metabolism of cells was hindered, and the structure of algae cells were broken and disintegrated (there was no photo of cell rupture), and the number of cells decreased [22]. By comparing the stress effect of three kinds of antibiotics on algae, it can be found that when the concentration of antibiotics was 50μg/L, the largest decrease in cell density of Chlorella is Ofloxacin (cell density decreased by 53.33%), followed by Dehydrated Erythromycin (cell density decreased by 41.54%), and finally Sulfamethoxazole (cell density decreased by 32.79%).

It can be seen that Ofloxacin has the greatest toxicity to Chlorella under this concentration, and Sulfamethoxazole has the greatest toxicity to Chlorella.

5.3.2. Effect of Antibiotics on Chlorophyll a Content in Algae. Chlorophyll is an important index to evaluate plankton productivity such as algae [23]. Chlorophyll a content of algae will change when water is polluted [19]. Riethman [24] found that the increase of Chlorophyll a content could promote the growth of algae, which might be to protect cells from the damage caused by environmental pollutants. Therefore, Chlorophyll a content can be used as an important indicator of algae growth and one of the indicators for environmental risk assessment.

Chlorophyll a content of Microcystis aeruginosa under Sulfamethoxazole stress varied with concentration and stress time as shown in Figure 4. When the concentration of Sulfamethoxazole was 0.05-5μg/L, the Chlorophyll a content of Microcystis aeruginosa did not change significantly within 24h. When the concentration of Sulfamethoxazole was 50μg/L, the Chlorophyll a content of Microcystis aeruginosa was the lowest, which was reduced by about 33% (compared with the control group). In the 48h stress growth cycle, the Chlorophyll a content of Microcystis aeruginosa increased first and then decreased. When the concentration of Sulfamethoxazole was 5μg / L, the Chlorophyll a content was the highest, but it was 18% lower (compared with the control group). This indicated that Sulfamethoxazole also had a certain inhibitory effect on the formation of Chlorophyll in Microcystis, and this inhibitory effect was more significant with the prolongation of time.

For Chlorella, during the stress growth cycle at 24h, when the concentration of Sulfamethoxazole was 0.05μg/L-5μg/L, the Chlorophyll a content of Chlorella increased by 7%, 11% and 15%, respectively (compared with the control group). Chlorella Chlorophyll a content began to decline (Sulfamethoxazole concentration >50μg/L), which was lower than the control group 8%. In the 48h stress growth cycle, when the concentration of Sulfamethoxazole was 0.05μg/L-5μg/L, the Chlorophyll a content of Chlorella was inhibited (8%, 4%, 1% lower than the control group) but showed a trend of increasing with the increase of concentration. the Chlorophyll a content decreased significantly (Sulfamethoxazole concentration>50μg/L), which was lower than 12% of the control group.
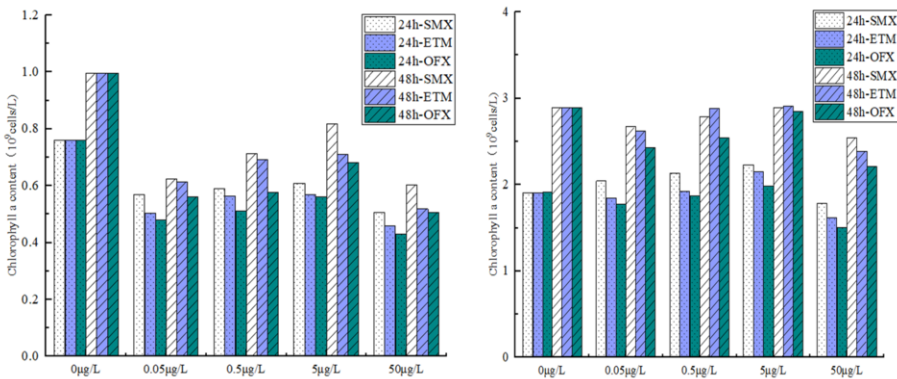
a. The effect of antibiotics on the content of Chlorophyll a in Microcystis aeruginosa.

b. Effects of antibiotics on the content of Chlorophyll a in Chlorella.

Figure 4. Effect of three antibiotics on the content of Chlorophyll a.

Under Dehydration Erythromycin stress, the Chlorophyll a content of Microcystis aeruginosa was lower than that of the control group. When the concentration of erythromycin dehydrate was 5 μ g/L, the Chlorophyll a content of Microcystis aeruginosa was lower than that of the control group by 25% and 29% in the stress growth cycles of 24h and 48h, respectively. When the concentration of erythromycin dehydrate was 0.5 μ g/L and 5 μ g/L, the Chlorophyll a content of Chlorella was higher than that of the control group in the stress growth cycle at 24h, which was higher than that of the control group by 1% and 11%. The content of Chlorophyll a was the highest when the concentration of erythromycin was 5 μ g/L in 48h stress growth cycle. When the stress concentration was 50 μ g/L, the content of Chlorophyll a was the lowest.

Under different concentrations of Ofloxacin stress, the Chlorophyll a content of Microcystis aeruginosa was inhibited to some extent. At the concentration of 5 μ g / L, they were lower than the control group by 26% (24h), 32% (48h). When the concentration was 50 μ g / L, the Chlorophyll a content was the lowest, which was lower than the control group by 43% (24h) and 49% (48h), respectively. For Chlorella, during the stress growth cycles of 24h and 48h, the overall trend of Chlorophyll a content in Chlorella increased slightly with the change of Ofloxacin concentration, and decreased rapidly after exceeding a certain concentration range. When the concentration of Ofleroxacin was 5 μ g/L, the Chlorophyll a content of Chlorella was the maximum. When the concentration of Ofleroxacin was 50 μ g/L, the content of Chlorophyll a decreased by 24% compared with the control group.

6. Conclusion

The study found that there are 5 types of 15 antibiotics were detected in the water of four urban lakes in Xi'an, with a concentration of ND-280.16ng/L. SMX, SMM, OFX, RTM and ETM are the main types of antibiotics. Ecological risk assessment shows that the five antibiotics in Tao Huatan are at high-risk level; SMM, OFX, and ETM in the water of Hancheng Lake and Xingqing Lake are at high-risk level; SMM and OFX in the water of Nanhu Lake are at a high risk level. Three typical antibiotics in the water have a certain inhibitory effect on the physiological activities of Microcystis aeruginosa and Chlorella, showing certain physiological toxicity. The magnitude of this toxicity is related to the concentration of antibiotics and the duration of stress.

Recommendations

This paper studied the effects of three antibiotics on Microcystis aeruginosa and Chlorella at a certain concentration. The effects of these antibiotics on other organisms and the transmission process in the food chain need further study. We believe that not only should environmental management departments pay attention to the impact of emerging pollutants such as antibiotics on the water environment, but also pay attention to monitoring and controlling the content of such pollutants in the discharge and treatment of sewage. For researchers, it is necessary to further study the degradation mechanism and technology of emerging pollutants and reveal their migration and transformation process in the environment.

References

[1] Jones O A H, Voulvoulis N, Lester J N. Aquatic environmental assessment of the top 25 English prescription pharmaceuticals. Water Research. 2002 Dec;36(20): 5013-5022.

[2] Ye M，Sun M，Feng Y. Effect of biochar amendment on the control of soil sulfonamides, antibiotic-resistant bacteria, and gene enrichment in lettuce tissues. Journal of Hazardous Materials, 2016 Oct;309(0): 219-227.

[3] Ding H J, Zhong J Y, Wu Y X, Zhang W H, Zou B C. Characteristics and ecological risk assessment of antibiotics in five city lakes in Nanchang City, Lake Poyang Catchment. Journal OF Lake Sciences 2017 Jul;29(04):848-858.

[4] Wang R J, Qiuqian L L, Li G X, Zong Y N, Tang J F, Xu Y Y. Distribution characteristics and ecological risk assessment of selected antibiotics in Moon Lake, Ningbo City. Journal OF Lake Sciences. 2018 Nov;30(06):1616-1624.

[5] Zhang Q Q, Ying G G, Pan C G. Comprehensive evaluation of antibiotics emission and fate in the river basins of China: Source analysis, multimedia modeling, and linkage to bacterial resistance. Environmental Science &Technology. 2015 Jun;49 (11) :6772-6782.

[6] Tang M. Study on the migration and transformation of pollutants in urban landscape water -Take Taohua Lake for example. Xi'an University of Technology; 2019. p.176-183.

[7] Yu J Z. The Characteristics of Water Quality in Time and Space and The Pollution Analysis in The Hancheng Lake of Xian. Xi`an University of Architecture and Technology; 2016. p. 37-49.

[8] Ministry of Ecology and Environment of the People's Republic of China, Water quality sampling---technical regulation of the preservation and handling of samples. http://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/shjbh/shjzlbz/200206/t20020601_66497.

[9] Zhou L J, Ying G G, Liu S. Simultaneous determination of human and veterinary antibiotics in variousenvironmental matrices by rapid resolution liquid chromatography electrospray ionization tandem mass spectrometry. Journal of Chromatography A. 2012 Aug;1244(00):123-138.

[10] Meng T, Cheng W, Wang M. Occurrence of antibiotics in rural drinking water and related human health risk assessment. Environmental Technology. 2019 May;23(01):47-75.

[11] Hernando M D, Mezcua M, Fernández-Alba A R, Barceló D. Environmental risk assessment of pharmaceutical residues in wastewater effluents, surface waters and sediments. Talanta. 2005 Apr;69(2):334-342.

[12] Xiao X X, Wu Y X, Ding H J, Wan L, Yang W F, Zhang W H. Pollution Characteristics of Antibiotics and Antibiotic Resistance Genes in Urban Lakes of Wuhan. Environmental Science &Technology. 2019 Mar;42(03):9-16.

[13] Wei H, Wang J W, Yang X Y, Sun B C, Li K B, Zhang J T. Contamination characteristic and ecological risk of antibiotics in surface water of the Weihe Guanzhong section. China Environmental Science. 2017 Jun;37(06):2255-2262.

[14] Xu W H, Zhang G, Zou S C, Li X D, Liu Y C. Occurrence and Seasonal Changes of Antibiotics in the Victoria Harbour and the Pearl River,South China. Envirnomental Science. 2006 Dec;(12):2458-2462.

[15] Tang J, Shi T Z, Wu X W, Cao H Q, Li X D, Hua R M,Tang F, Yue Y D. The occurrence and distribution of antibiotics in Lake Chaohu, China: seasonal variation, potential source and risk assessment. Chemosphere; 2015. p.122-132.

[16] Wang W H.The Distribution,Transformation and Risk Assessment of Typical Antibiotics in the Songhua River Basin of Harbin Secion. Northeast Forestry University;2018. p. 53-73.

[17] Li W H, Shi Y L, Gao L H, Liu J M, Cai Y Q. Occurrence of antibiotics in water, sediments, aquatic plants, and animals from Baiyangdian Lake Lake in North China. Chemosphere. 2012 Nov;89(11)1307-1315.

[18] Chen K, Zhou J L. Occurrence and behavior of antibiotics in water and sediments from the Huangpu River, Shanghai, China. Chemosphere. 2014 Jan;95(0):604-612.

[19] Yang W W, Wu Y X, Zhang W H. Toxicity of enrofloxacin and erythromycin thiocyanate on Microcystis aeruginosa. China Environmental Science. 2013 Oct;33(10): 1829-1834.

[20] Qian H F, Li J J, Pan X J. Effects of streptomycin on growth of algae Chlorella vulgaris and Microcystis aeruginosa. Environmental Toxicology. 2012 Apr;27(4): 229-237.

[21] Calabrese E J. Hormesis: principles and applications forpharmacology and toxicology. Amercian Journal Pharmacology&Toxicology. 2008 May;3(1):59-71.

[22] Hong H C, Zhou H Y, Lan C Y. Toxicity effects of pentachlorophenol on the growth, the contents of pigments and soluble protein of Scenedesmus obliquus. Research of Environmental Sciences. 2003 Nov;16(6):23-25.

[23] Zhang X H, Wan T, Cheng W, Wang M, Ren J H. Effects of quinolones and sulfonamides on the growth of green algae. Journal of Water Resources and Water Engineering. 2018 Aug;29(04):115-120.

[24] Riethman H, Bullerjahn G, Red K J. Regulation of cyanobacterial pigment-protein composition and organization by environmental factors. Photosynth Res. 1988 Oct;18(1): 133-161.

413

Restoration Effect Evaluation of Artificial Reefs Based on Bayesian Networks

Xin LV[a], Yifei ZHANG[a1], Xin FANG[a,b1], Zonghao HOU[a]

aSecond Institute of Oceanography, Ministry of Nature Resources, Hangzhou 310012, China

bSchool of Geography and Ocean Science, Nanjing University, Nanjing 210093, China

Abstract. To meet the increasingly urgent need for ecological restoration effect evaluation, the ecosystem health status of reefs was described, and an ecosystem health evaluation model of artificial reefs (ARs) based on Bayesian networks (BNs) was established. By comparing the probability of the ecological health status between restored areas and control areas, we assessed the AR ecological restoration effect of the Qinhuangdao project in 2012. The results show that this project had a remediating effect in May and September, with clear repair effects on the water environment, sediment environment, and fishery resources. The sensitivity of each indicator was calculated, and organic carbon and benthos biomass was identified as the most sensitive factors. This study will provide the basis for the further development of restoration measures.

Keywords. Artificial reefs (ARs), ecological restoration, Bayesian networks (BNs), effect assessment, ecosystem health

1. Introduction

Significant degradation of marine ecosystems has occurred owing to human disturbances [1, 2]. Artificial reefs (ARs) both repair the water environment and provide habitats for fish, which is conducive to fishery proliferation [3, 4, 5], and helps to counteract the degradation of the ecosystem. A lot of ecological restoration work has been conducted on ARs. Therefore, it is crucial to evaluate the ecological restoration effect of ARs objectively.

The ecological restoration evaluation of ARs has been mainly carried out using two methods: the comparison of individual indicators and the calculation of a comprehensive index. The former has been conducted using various aspects, such as fishery resources [6], the benthic community level [7], the water quality environment, sediment status, and marine biological resources [8] compared the biomass and species diversity of fishery resources in before and after reef construction. Single indicator comparison is simple, but requires accurate and complete data [9]. Moreover, Zhao et al. and Tong et al. comprehensively evaluated the ecosystem health of restoration area and control area by calculating the ecosystem health index (EHI) [10, 11]. Fu et al. assessed the ecological

---

restoration effect by calculating the weighted average of the changing rate of each indicator [12]. Wang et al. used the exergy value to reflect the community structure, stability, and organization degree, and thus to evaluate the health status of animal communities in the control and restoration area. The comprehensive evaluation index provides a direction for artificial reef ecological restoration [13]. Furthermore, the concept of ecosystem health contains kinds of possibilities, using probability to evaluate ecosystem health uncertainty can help managers understand the mechanism behind the model and make more scientific decisions.

The Bayesian network (BN) can conduct probability reasoning from a parent node to a child node and vice versa. At the same time, it is especially well suited to handle missing data, making it suitable for risk assessment, diagnosis, and decision analysis [14, 15]. Based on the logical characteristics of the BN, we evaluated the ecological restoration effect of ARs in Qinhuangdao, China. Therefore, we regarded the ecosystem health status as a variable with its own probability distribution, and demonstrated the uncertainty of ecosystem health status in the study area in the form of a probability so as to evaluate the restoration effect of ARs.

The objectives of present research taking the Qinhuangdao AR restoration project as a case study, are: (1) to propose an index integrating water quality indicators, sediment environment indicators, biotic indicators and fishery environment; (2) to build a BN model based on the index for assessing the healthy state of the Qinhuangdao AR ecosystem; (3) to compare the healthy state of the control area and restoration area thus evaluating the restoration effect of ARs

2. Study Area and Data Collection

2.1. Study Area

The Qinhuangdao coastal areas are important fish spawning sites and feeding grounds in China. In recent years, they have suffered from problems such as the extinction of marine organisms, reduction of biodiversity, and declining catches due to overfishing, reclamation, and water pollution [16]. To restore the deteriorating coastal environment of Qinhuangdao, the relevant departments conducted a restoration project in 2010, including the creation of an AR restoration area (Figure 1).
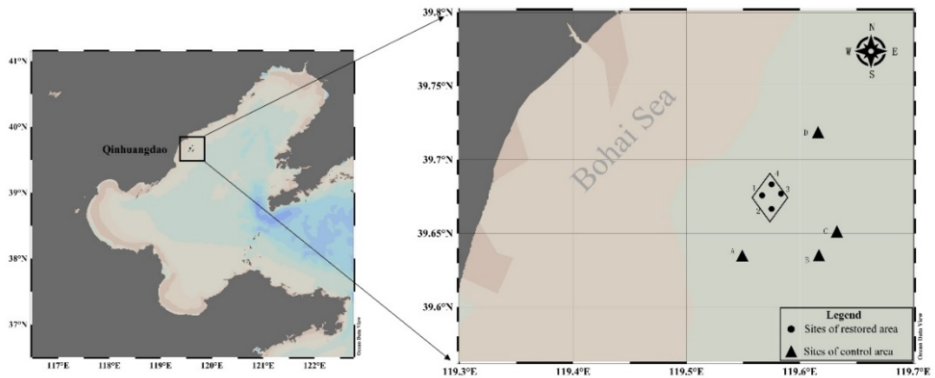
Figure 1. Study area.

2.2. Data Collection

This study involved data including biochemical oxygen demand, organic carbon, the phytoplankton diversity index, the zooplankton diversity index, and the species number of swimming animals and biomass, which were all collected from Xu et al. [17]. These data were measured on two survey voyages in May and September 2012, respectively. The distribution of survey stations is shown in Figure 1. Sites 1 to 4 are the AR restoration areas, while A to D is the control site outside the reefs.

3. Methods

3.1. Theoretical Background and Applications

BNs, also known as Bayesian belief networks, are composed of directed acyclic graphs and node probability tables (NPTs), which are used to describe the dependence between variables and the quantitative relationship between variables, respectively [18].

The theoretical basis of BNs is the Bayesian formula, shown in Equation (1). BN is a representation of the decomposition of joint probability distribution. The probability distribution of the target node is expressed by a joint distribution containing n variables, as shown in Equations (2) and (3):

$$P(\pi(X_i) \mid X_i) = \frac{P(\pi(X_i))P(X_i \mid \pi(X_i))}{\sum_{i=1}^{n} P(\pi(X_i))P(X_i \mid \pi(X_i))} \tag{1}$$

$$P(X_i) = \sum_{i=1}^{n} P(\pi(X_i))P(X_i \mid \pi(X_i)) \tag{2}$$

$$p(X_1,\ldots,X_n) = \prod_{i=1}^{n} P(X_i \mid \pi(X_i)) \tag{3}$$

where $P(\pi(X_i) \mid X_i)$ is the posterior probability, $P(\pi(X_i))$ is prior probability, $P(X_i)$ is the edge distribution of the root node, $P(X_i \mid \pi(X_i))$ is the conditional probability, and $p(X_1,\ldots,X_n)$ is the joint probability. The probability of the parent node is corrected while the observation value is updating, and the observation results can be input at any node.

BNs have the advantage of combining expert knowledge with objective data. Forio et al. used this characteristic to predict the water quality of typical multi-functional tropical watersheds [19]. Havron et al. and Mo used BNs' expression in the form of probability [20, 21]. The former simulated the probability of several macrobenthos' occurrence in different geographical locations to analyze the habitat suitability, and the

latter predicted ecological vulnerability. The results of the abovementioned studies indicate that BNs can be used to analyze the uncertainty of the ecological environment.

3.2. Research Framework

A systematic framework is proposed in six steps to describe how BNs can be applied in assessing the ecological restoration effect:

Step 1. Confirm the evaluation system. Based on the evaluation requirements and the availability of data, we took ecosystem health as the target node took fishery resources, water environment, sediment environment, and biological environment (B1 to B4) as the criterion layer nodes, and selected several indicators as the parent node to construct a hierarchical model.

Step 2. Build the BNs' structure. Using some structural forms to define the graphic part of BNs can accelerate the development process of BNs and improve their quality [22]. The definitional/synthetic idiom is the most common form, and the characteristic of this kind of structure defines the synthetic node according to the parent node. In this paper, the intermediate node was defined by classifying the indicators, and then the target node was defined according to the concept of the intermediate node so as to construct AR ecological health evaluation system.

Step 3. Calculate the NPTs. Determining the BN parameters involves constructing NPTs, which can be constructed by manually filling out the probability table and inputting the eigenvalues of the measured data. We selected the latter, which mainly includes the following points:

① Data standardization

The data set was standardized according to Equation (4), and each index was dimensionless.

$$x^* = \frac{x - x_{min}}{x_{max} - x_{min}}$$

(4)

where x is measured data; x^* is standardized data; and x_{min} and x_{max} are the minimum and maximum value in a dataset, respectively.

② Ranked node

The prior probability of root nodes in the model needs to be given when using BNs for prediction. Hierarchical nodes make it easier to build and edit BNs than others [23]. Five evaluation grades were set on root nodes. Considering that the standardized data fell in the interval of [0,1], we divided this interval into five grades as 'VL/L/M/H/VH,' with 0.2 as the interval, and preliminarily judged the evaluation grade of each data point. The data were divided into four categories according to seasons and regions. Averaging all site values for each evaluation index by classification, we determined the comprehensive grade of the root node as the prior knowledge according to the interval of the average value.

When using hierarchical nodes to describe variables, it is necessary to ensure that the node state is consistent with the good or bad trend of the evaluation target; that is, the higher the reverse index value in this study, the worse the corresponding node state [22].

③ Produce NPTs

The truncated normal distribution (TNormal) was introduced to define the statistical function in the interval [0,1]. The distribution is a finite endpoint, all nodes are limited in [0,1], and the expression is $TNormal(\mu, \sigma^2, 0, 1)$. NPTs could be obtained by inputting the mean expression and variance of the relationship between nodes. Considering the different comparison objects, the corresponding standardized station data were selected to calculate the mean and variance.

Step 4. Allot the weight of evaluation indicator. The mean of the superior node could be linearly added according to the mean of the inferior node multiplied by the weight; the variance of superior nodes could be represented by the reciprocal of the sum of the weights of inferior nodes.

The weight value of intermediate node B was determined by equal weight, and the weight value of root node C was calculated by principal component analysis in SPSS25.0 software (IBM).

Step 5. Deduce the probability distribution of target node. In order to facilitate the comparison of results, the intermediate node B was divided into five evaluation grades, and the target node A was divided into seven evaluation grades. According to the distribution of probability in different levels, the levels of target nodes and intermediate nodes were determined.

Step 6. Identify sensitive factors. Sensitivity can reflect the average influence of the change of variable state on the state of the target node [24]. Through sensitivity calculation and analysis, the key factors affecting the health of AR ecosystem could be identified, and the key repairing indexes in ecological restoration projects could be clarified. The calculation of sensitivity is as follows:

$$I_a(C_k) = \frac{1}{P_k} \sum_{c_k}^{P_k} \frac{|P(C_k = c_k \mid A = a) - P(C_k = c_k)|}{P(C_k = c_k)}$$

(5)

where c_k is the state of root node C_k, P_k is the number of states, and a is the state of the target node A.

4. Model Construction

4.1. Index System for Assessing AR Ecosystem Health

The BN model established in this study contains three hierarchical structures (Figure 2). The root node is each specific index. The intermediate node is obtained by classifying and defining the meaning of the root node, and the target node is the AR ecological health status (A).
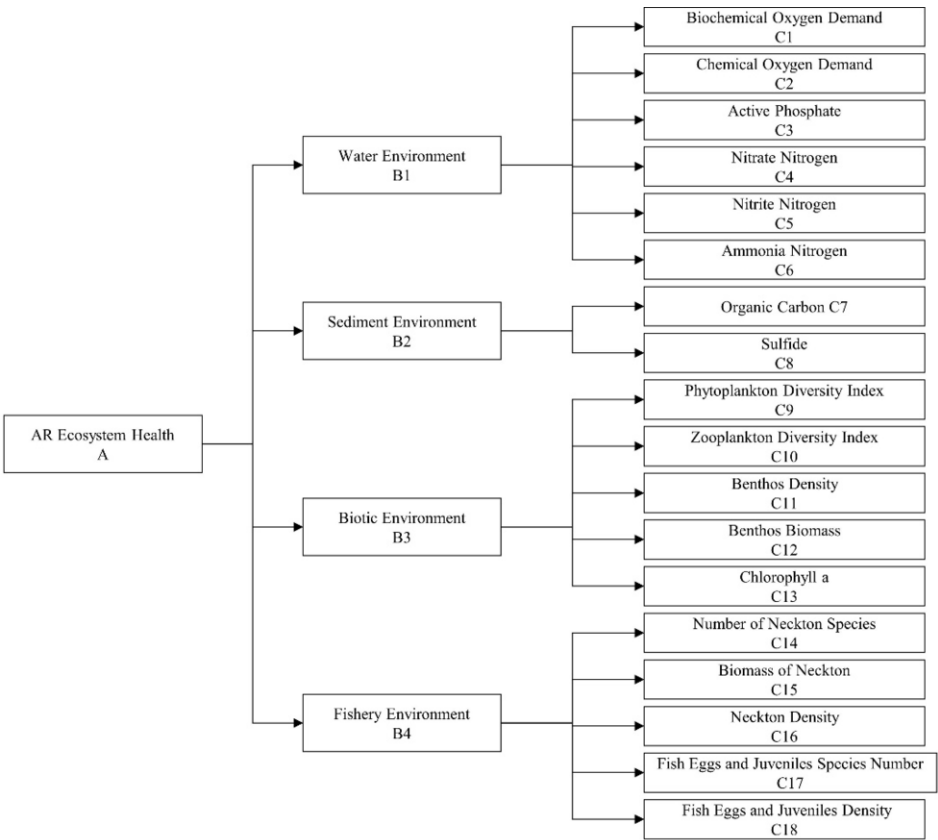
Figure 2. Health evaluation index system of the AR ecosystem in Qinhuangdao city.

4.2. Construction of BNs Structure

According to the hierarchical structure between nodes shown in Figure 2, the BN topology for evaluating the health of AR ecosystem is constructed (Figure 3) (take the situation of the restored area in May as an example).

4.3. Data Processing

The mean, variance, and weight of each index are determined to generate NPTs of variables, and the measured data are classified as the prior knowledge of the input model. The mean and variance of standardized station data are shown in Table 1. C17 and C18 (number and density of eggs, larvae, and juveniles) data in September were 0, so we manually set the probability of 'very low' in the node probability Table to 1, and the probability of other grades was 0.

The interval [0,1] was divided into five grades with intervals of 0.2. The positive index (C9–C18) was divided into grades from 'very low' to 'very high' and the reverse index (C1–C8) was the opposite.
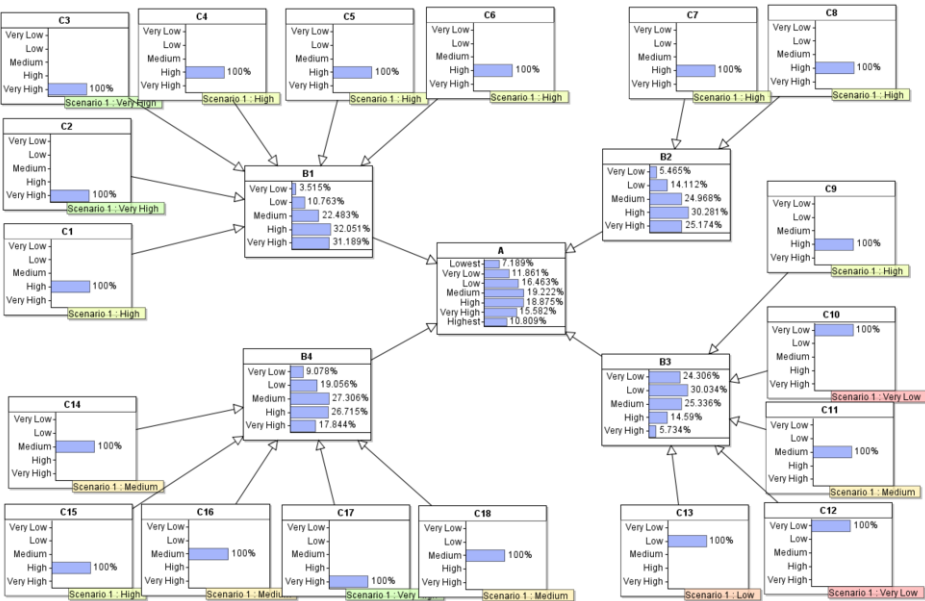
Figure 3. BN model built in AgenaRisk for assessing the AR ecosystem health.

Table 1. Processed data and divided grades.

Indicators	Weight (%)	May				September			
		Mean	Variance	Grade of restored area	Grade of control area	Mean	Variance	Grade of restored area	Grade of control area
C1	27	0.400	0.115	H	M	0.417	0.097	M	L
C2	15	0.334	0.102	VH	M	0.426	0.100	VH	H
C3	27	0.375	0.172	VH	L	0.330	0.083	H	M
C4	13	0.448	0.101	H	L	0.640	0.073	L	VL
C5	9	0.438	0.105	H	L	0.309	0.123	VH	L
C6	9	0.392	0.157	H	M	0.323	0.087	M	L
C7	51	0.388	0.124	H	H	0.215	0.040	H	M
C8	49	0.511	0.088	H	L	0.397	0.077	H	L
C9	16	0.408	0.091	H	L	0.597	0.101	VH	H
C10	17	0.433	0.136	VL	M	0.610	0.115	VH	VH
C11	17	0.342	0.110	M	VL	0.364	0.090	M	VL
C12	26	0.208	0.094	VL	VL	0.189	0.099	L	VL
C13	24	0.250	0.096	L	VL	0.478	0.113	L	VL
C14	24	0.542	0.109	M	M	0.500	0.083	M	L
C15	14	0.488	0.126	H	VL	0.499	0.152	VH	L
C16	20	0.304	0.091	M	VL	0.234	0.103	M	VL
C17	15	0.500	0.250	VH	VL	-	-	VL	VL
C18	27	0.340	0.084	M	VL	-	-	VL	VL

VL: very low; L: low; M: medium; H: high; VH: very high.

5. Results and Discussion

Using BNs, the mean (or the function used to calculate the mean) and variance were input into the AgenaRisk software (Agena) to generate the prior probability distribution,

and then the level of the root node was input as the observation data to complete the probability calculation. By comparing the probability of each AR ecosystem health status of the restored area and control area in Qinhuangdao, we found that that the ecological status of the restored area was better than that of the control area after restoration, and the ARs had some restoration effect on ecology.

5.1. Assessment of the AR Ecological Restoration Effect

Taking the data of the restored area in May, for example, the probability distribution of each node in the restored area was obtained by inputting the pre-calculated root node level as the observation value into the software AgenaRisk (Figure 3). According to the maximum probability principle, the ecosystem health grade of the restored area in May was 'middle'; likewise, the grade of node B1 was 'high'.
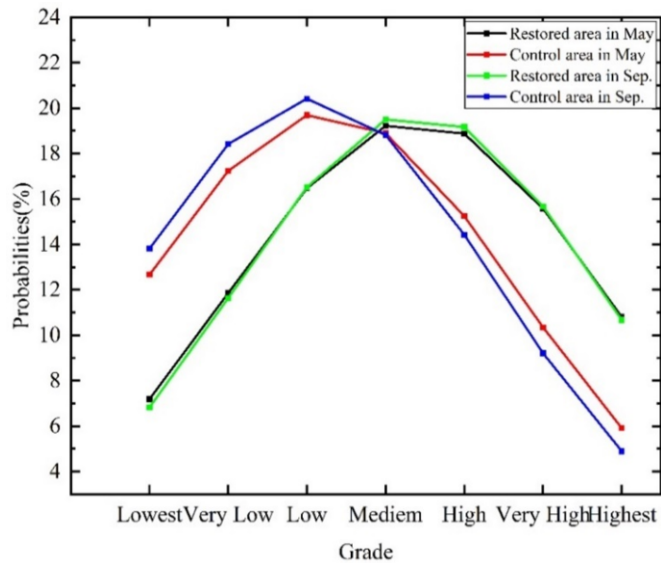
Figure 4. Probability distribution of ecosystem health at all levels.

The probability distributions of the target nodes in the restored and control area in May and September were counted and are shown in Figure 4, and the corresponding criterion level results are shown in Table 2. In May, the ecosystem health rating of the restored area was 'medium', and that of the control area was 'low'; in September, the ecosystem health rating of the restored area was 'medium,' and that of the control area was 'low'. The overall ecosystem health status of the restored area was better than that of the control area. Therefore, we argue that the AR in May and September had a restoration effect on the ecological environment of Qinhuangdao. Moreover, the water environment, sediment environment, and fishery resources were repaired.

The results of this study are somewhat different from those of Xu. The remediation effect of sediments in May and September was not obvious, but the results of this study show that there was some remediation effect. The biotic environment remediation effect was obvious in May, while our results show that both the restored and control area had the 'low' grade, revealing that the repairing effect was not obvious. Xu assigned value to each indicators through differential significance analysis and calculated the comprehensive index value to assess the restoration effect, which was subjective.

Different assignment gradients also affect the final results. This paper defines variables as hierarchical nodes, and the difference in the hierarchical led to the change of the evaluation level, which led to a difference in the evaluation results. The results of this study are consistent with those of Xu's study on water environment and fishery resources. Xu's results show that the repairing effect in May and September was obvious and slight, respectively, which is consistent with the results of this paper.

Table 2. Results of ecosystem health assessment in the criterion layer.

Grade	May		September	
	Grade of restored area	Grade of control area	Grade of restored area	Grade of control area
Water environment (B1)	High	Medium	High	Low
Sediment environment (B2)	High	Medium	High	Medium
Biotic environment (B3)	Low	Low	Medium	Low
Fishery resources (B4)	Medium	Very Low	Low	Very Low

5.2. Identification of Sensitive Factors

Based on the model constructed, it was assumed that the ecosystem health is in a good state, and we set the observation value of the target node as 'Highest', adversely reasoning the probability distribution of each root node according to Equation (1). Moreover, the sensitivity of each root node was calculated according to Equation (5) (Figure 5). It can be seen that the indicators C1, C7, C12, and C18 in B1, B2, B3, and B4, respectively, had a high level of sensitivity. Similarly, we set the observation value of the target node as 'High', and the result shows that C1 (biochemical oxygen demand), C7 (organic carbon), C12 (benthos biomass), and C18 (density of fish eggs and larvae) had the highest influence. Similarly, analysis of the sensitive node in the case of September showed that C3 (active phosphate), C7 (organic carbon), C12 (benthos biomass), and C16 (swimming animal density) were the more sensitive factors.
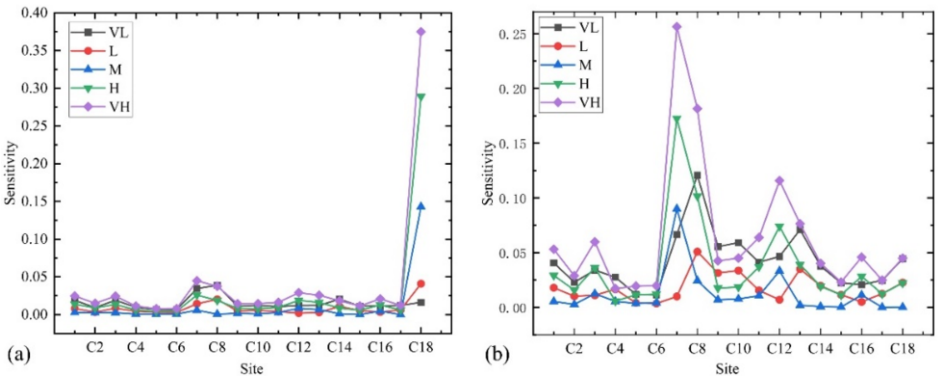
Figure 5. BN model built in AgenaRisk for assessing AR ecosystem health.

When conducting surveys, the value of sensitive factors should be carefully measured to improve the accuracy of evaluation results; in future restoration work, the content of labile phosphate in the water environment should be strictly controlled, an appropriate-biochemical environmental-condition is required, and the biomass of benthic animals and the biological density of swimming animals should be increased, which will all help improve the AR ecological restoration effect.

6. Conclusion

Procedures for assessing AR ecological restoration effect were proposed in the present study. As a case study of the Qinhuangdao restoration project, a set of indicators involving the water environment, sediment environment, biological environment, and fishery resources was presented and applied to the Qinhuangdao ARs ecological restoration effect assessment. The assessment results show that the restoration project had a comprehensive repair effect on the ecology. Sensitivity analysis revealed that organic carbon and benthos biomass were important variables determining ecological health. The results indicate that BN can intuitively express the relationship between variables, and it is feasible to evaluate the effect of AR restoration based on the BN. Moreover, the proposed method can be used in other types of comprehensive ecological restoration evaluation.

References

[1]   Jouffray JB, Blasiak R, Norström AV, Österblom H, Nyström M. The blue acceleration: The trajectory of human expansion into the ocean. One Earth. 2020;2(1):43-54.
[2]   Li YQ and Tang XX. Marine restoration ecology. Qingdao: China Ocean University Press;2016.153 p.
[3]   Lima JS, Zalmon IR, Love M. Overview and trends of ecological and socioeconomic research on artificial reefs. Marine Environmental Research. 2019;145:81-96.
[4]   Pitcher TJ, Buchary EA, Hutton T. Forecasting the benefits of no-take human-made reefs using spatial ecosystem simulation. ICES Journal of Marine Science. 2002;59(suppl):S17-S26.
[5]   Zhang R, Liu H, Zhang Q, Zhang H, Zhao J. Trophic interactions of reef-associated predatory fishes (Hexagrammos otakii and Sebastes schlegelii) in natural and artificial reefs along the coast of North Yellow Sea, China. Science of The Total Environment. 2021;791:148250.
[6]   Lima JS, Sanchez-Jerez P, dos Santos LN, Zalmon IR. Could artificial reefs increase access to estuarine fishery resources? Insights from a long-term assessment. Estuarine, Coastal and Shelf Science. 2020;242:106858.
[7]   Hammond M, Bond T, Prince J, Hovey RK, McLean DL. An assessment of change to fish and benthic communities following installation of an artificial reef. Regional Studies in Marine Science. 2020;39:101408.
[8]   Han YY, Yin R, Sun GQ, Yu, QH, Liu, YF, He ZW and Gong CG. Effect evaluation of artificial reef construction in Beidaihe National Marine Ranch Demonstration Zone. Hebei Fisheries. 2020(04):24-7+57.
[9]   Liu SB, Wang ZH, Lin LW, Yang PH and Zhang S Y. Preliminary evaluation on effects of artificial reef project in Shengsi. Journal of Shanghai Ocean University. 2007;16(3):297-302.
[10]   Tong F, Zhang XM, Wu ZX and Zhang PD. The ecosystem health assessment of artificial reef areas in Lidao Island, Rongcheng. Periodical of Ocean University of China. 2014;44(04):29-36.
[11]   Zhao RR, Gong PH, Zhang Y, Yuan W, Guan CT, Shi MM, Xie ZH and Li J. Ecosystem health assessment of artificial reef area in Long Island. Progress in Fishery Sciences. 2019;40(06):9-17.
[12]   Fu XM, Tang JY, Wu WQ and Zhang S. Evaluation of ecological restoration performance in Haizhou Bay, Lianyungang. Journal of Dalian Fisheries University. 2017;32(01):93-8.
[13]   Wang Y, Hou CQ, Wang XY, Zhang BL, Chen W and Xu XF. Preliminary evaluation on proliferation effects of artificial reefs in Live Oyster Reef Area, Tianjin, China. Transactions of Oceanology and Limnology. 2018(02):137-45.
[14]   Yao XW, Xu KL, Yan F and Tang GC. Research on the risk evaluation model for composite techniques and its field application. Journal of Northeastern University (Natural Science). 2015;36(5):737-42.
[15]   Chen J, Wu YW, Li HZ, Qian XM and Yuan MQ. Risk analysis of burning and explosion of gas pipeline network based on dynamic Bayesian network. Transactions of Beijing Institute of Technology. 2021;41(7):696-705.
[16]   Li XW, Zhao JM, Liu H, Zhang H and Hou XY. Status, Problems and optimized management of spawning, feeding, overwintering grounds and migration route of marine fishery resources in Bohai Sea and Yellow Sea. Transactions of Oceanology and Limnology. 2018(05):147-57.

[17] Xu YF, Li YQ, Zhang HP, Gao WB, Wang S Z, Hu B C and Liu S J. evaluation index system and case application of ecological restoration effect in Artificial Fish (Algae) Reef Area. Hebei Fisheries. 2017;(01):42-50.

[18] Pearl J. Bayesian Networks: A model of self-activated memory for evidential reasoning. Proc of Cognitive Science Society (CSS-7). Pearl_CSS851985.

[19] Forio MAE, Landuyt D, Bennetsen E, Lock K, Nguyen THT, Ambarita MND, et al. Bayesian belief network models to analyse and predict ecological water quality in rivers. Ecological Modelling. 2015;312:222-38.

[20] Havron A, Goldfinger C, Henkel S, Marcot BG, Romsos C, Gilbane L. Mapping marine habitat suitability and uncertainty of Bayesian networks: a case study using Pacific benthic macrofauna. Ecosphere. 2017;8(7):e01859.

[21] Mo DY. A Bayesian network model and its application on ecological environment vulnerability assessment. Beijing: The University of Chinese Academy of Sciences. 2017.

[22] Fenton NE, Neil M. Risk assessment and decision analysis with Bayesian network. New York: CRC Press; 2012.p.314-68

[23] Fenton, N. E., Neil, M. Ranked nodes: A simple and effective way to model qualitative judgements in large-scale Bayesian networks. London; 2005.

[24] Wu XG, Li TJ, Lin JY, Ma J, Zhang LM and Liu WL. safety risk assessment of metro shield tunnel-induced adjacent bridge damage based on rough set and Bayesian network. Journal of Civil Engineering and Management. 2016;33(03):9-15+29.

The Study on Characteristics of Precipitation and Its Return Period Calculation in Wuhan in Recent 30 Years Based on Data Analysis

Junchao WANG[a, c], Yuan GAO [a, c1], Jintao YE [a, c], Haixia QI [a, b, c] and Jiaming LIU [d]

[a] *Hubei Key Laboratory for Heavy Rain Monitoring and Warning Research, Institute of Heavy Rain, China Meteorological Administration, Wuhan 430205, China*
[b] *Hubei key laboratory of water system science for sponge city construction (Wuhan University), Wuhan 430072, China*
[c] *Three Gorges National Climatic Station, Yichang 443000, China*
[d] *Changjiang Institute of Survey Planning and Design of a Limited Liability Company, Wuhan 430205, China*

Abstract. Meteorological big data has a wide geographical range, large space-time density, many data types and strong timeliness. It has become the requirement of the development of meteorological industry to quickly extract huge information and knowledge from big data to solve the problem of weather prediction. Based on the measured data of maximum one-hour rainfall from six representative rainfall stations in Wuhan from 1992 to 2021, the variation law, characteristic analysis and return period of different aging precipitation in Wuhan city in the past 30 years are analyzed. The results show that although the number of days of precipitation in Wuhan has increased year by year in the past 30 years, the days of rainstorm and more than rainstorm generally show a decreasing trend. The precipitation is mainly concentrated in spring (March-May) and summer (June-August), with the most in summer. The monthly precipitation is mainly concentrated in July, with the least precipitation in December. The maximum daily precipitation is between 55.1~285.7mm, and the average maximum hourly precipitation of 122.4mm reaches 98.6mm. At last, based on the parameters of GEV distribution, the maximum hourly precipitation, maximum 3h, 6h, 12h, 24h precipitation , continuous hourly precipitation, maximum daily precipitation and maximum continuous daily precipitation are fitted, and the values of different recurrence periods are estimated.

Keywords. Characteristic, meteorological, rainfall, return period, variation characteristics

1. Introduction

Urbanization is an important symbol of national modernization. According to the data of the seventh national census, the resident population in cities and towns in China is 901.99 million, accounting for 63.89% of the total population. Under the background of the accelerating process of urbanization, the hydrological characteristics of urban areas have changed greatly under the influence of a series of factors, such as the continuous expansion of urban construction areas, the increase of impervious area, the construction of drainage system and so on [1-3]. With the continuous improvement of urban population and asset density, the disaster losses caused by flood and waterlogging disasters in cities of the same scale are obviously increased [4-5]. According to the statistics of China Flood and drought disaster Bulletin, during the period from 2006 to 2016, floods occurred in more than 160 cities across the country, with an average annual direct economic loss of more than 200 billion Yuan RMB. The degree of dependence of cities on lifeline system is gradually increasing, and the impact of flood disasters is obviously beyond the scope of flooding [6-8]. Prevention of urban flood disasters has become an important work to ensure the safety of lives and property of urban residents [9-10].

In view of the new characteristics of urban flood disasters, in order to further enhance the ability of urban flood prevention and control and reduce flood risk, Wuhan actively establishes a comprehensive and systematic flood control engineering system and promotes the defense standards of flood control projects. In order to effectively reduce the loss of flood disaster in the flood control standard. However, at present, there are still a series of problems in how to systematically manage and prevent and control urban flood disasters under complex natural and cultural conditions. For this reason, the Yangtze River Survey, Planning and Design Research Co., Ltd. have carried out research on the key technologies to improve the waterlogging prevention capacity of urban agglomeration. In view of the fact that urban waterlogging is closely related to precipitation, if rainfall of 80mm to 100mm occurs in some urban areas in a short period of time, there will be many local floods. The Yangtze River Survey, Planning and Design Research Co., Ltd. specially entrusts Wuhan rainstorm Research Institute of China Meteorological Administration to carry out the analysis of urban rainfall law in Wuhan based on the precipitation data of Wuhan in the past 30 years, in order to analyze the environmental causes of frequent urban floods in Wuhan. In order to formulate more scientific urban flood prevention measures.

2. Analysis of the Characteristics of Annual Precipitation

According to the statistics of Wuhan National basic Weather Station, from 1992 to 2021, the annual precipitation in Wuhan is increasing year by year, the average annual precipitation is 1290.4mm, the maximum annual precipitation is in 2020, the annual precipitation is 2012.4mm, and the minimum annual precipitation is 899.8mm in 2001. The average annual precipitation days are 121.6 days, with an average of 86.1 days of light rain, 21.7 days of moderate rain, 8.9 days of heavy rain, 3.7 days of heavy rain, 1.1 days of heavy rain, the longest days of precipitation in 2016 and 2020, and the shortest days of precipitation in 2005 and 2011. There is no heavy rain in 10 years, and the largest number of heavy rain days in 2016 is 4 days. In 30 years, there are at least 2 rainstorm days per year, with the largest number of rainstorm days in 2004, with 8

days. Although the number of precipitation days in Wuhan has increased year by year in the past 30 years, the number of rainstorm and more than rainstorm days showed an overall decreasing trend (see figure 1(a), 1(b), 1(c)).
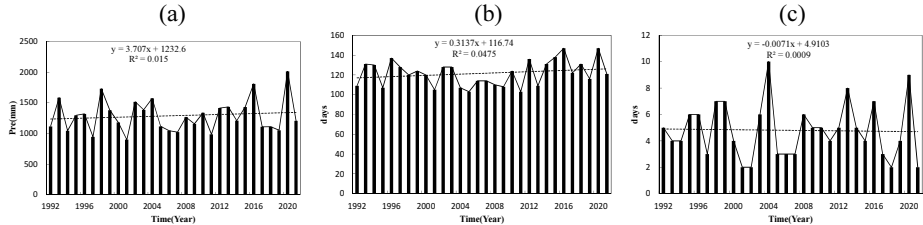
Fig.1 Distribution map of annual precipitation in Wuhan for many years (1992-2021) (a); Variation trend of annual precipitation days in Wuhan City for many years (1992-2021) (b); Variation trend of rainstorm and days above rainstorm in Wuhan City for many years (1992-2021) (c).

3. Analysis of Seasonal Precipitation Characteristics

The precipitation in Wuhan is mainly concentrated in spring (March-May) and summer (June-August) as shown in Figure2, with the most in summer, the average precipitation in spring is 345.2mm, the average precipitation in summer is 420.6mm, the average precipitation in autumn is 224.1mm, and the average precipitation in winter is 151.9mm. During the 30 years from 1992 to 2021, the maximum precipitation in spring appears in 2002, which is 653.8mm, and the minimum precipitation appears in 2011, which is 145.1mm; the maximum precipitation in summer appears in 2016, which is 1200.2mm, and the minimum precipitation appears in 2001, which is 214.4mm; the maximum precipitation in autumn appears in 2020, which is 424.4mm, and the minimum precipitation appears in 2007, which is 81.1mm. The maximum precipitation in winter is 220.1mm in 2020, and the minimum precipitation is 34.3mm in 1999.
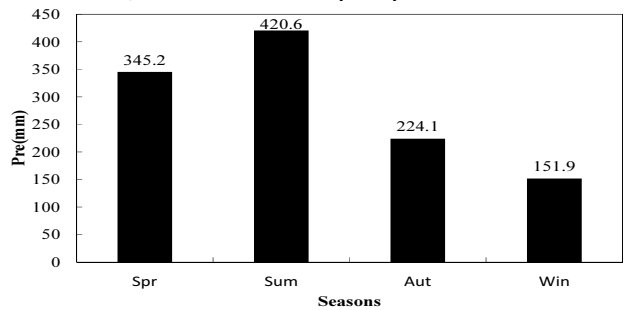
Fig. 2. Distribution of seasonal precipitation in Wuhan for many years (1992-2021).

4. Analysis of Monthly Precipitation Characteristics

The monthly precipitation in Wuhan is mainly concentrated in July as shown in Figure3, with an average annual precipitation of 235.6mm in July and the least in December, which is 29.4mm. The maximum value of multi-year monthly average precipitation is 758.4mm in July 1998, and the multi-year monthly minimum precipitation appeared in December 1999, which is 0mm (See Table 1 for details).
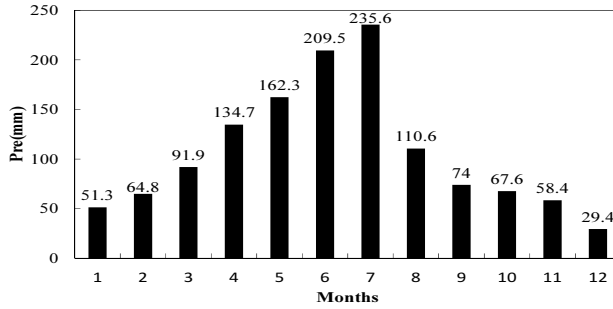
Fig. 3. Monthly precipitation distribution in Wuhan for many years (1992-2021).

Table 1. monthly precipitation statistics of Wuhan City.

January-June						
January-June Statistical content	1	2	3	4	5	6
Average monthly precipitation	51.3	64.8	91.9	134.7	162.3	209.5
Maximum monthly precipitation	113.2	122.9	225	333.6	344.2	469.1
Minimum monthly precipitation	15.6	8.4	23.9	22.9	70	53.2
July-December	7	8	9	10	11	12
Average monthly precipitation	235.6	110.6	74.0	67.6	58.4	29.4
Maximum monthly precipitation	758.4	244.1	207.8	173.1	143.4	88.9
Minimum monthly precipitation	39.6	14.4	1	1.3	0.2	0

5. Analysis of Daily Precipitation Characteristics

According to the precipitation data of Wuhan National basic Meteorological Station, during the 30 years from 1992 to 2021, the maximum daily precipitation in Wuhan is between 55.1~285.7mm, with an average of 122.4mm, among which the maximum daily precipitation in 1998 is the largest, reaching 285.7mm, and the minimum in 2017, which is 55.1mm. The maximum continuous daily precipitation in Wuhan is between 93.2~582.5mm, with an average of 218.93mm, in which the maximum sustained daily precipitation in 2016 is the most and that in 2018 is the least. The longest continuous precipitation days in Wuhan are 16 days (1992.03.13-1992.03.28) in 1992, and the process precipitation is 174.1mm. In 1995, the longest continuous precipitation days are only 4 days (1995.02.10- 995.02.13), and the process rainfall is 32.1mm. In the past 30 years, the process rainfall of the longest continuous precipitation in 2016 is the largest, reaching 582.5mm, and the process rainfall of the longest continuous precipitation in 2011 is the smallest, which is 9.7mm.

6. Analysis of the Characteristics of Short-Duration Precipitation

Affected by the effect of urbanization, the occurrence probability and rainfall intensity of high-intensity local torrential rain in urban central area are greatly increased, which increases the natural risk of flooding in the city. In recent years, extreme rainstorm events occur frequently in Wuhan, and the intensity of short-duration precipitation directly affects the degree of rainstorm waterlogging disaster. In order to better carry

out the prevention and control of rainstorm and waterlogging disasters in Wuhan, according to the hourly precipitation data of the national basic weather station in Wuhan, the maximum hourly precipitation, maximum 3 h precipitation, maximum 6 h precipitation, maximum 12 h precipitation, maximum 24 h precipitation and maximum continuous hour precipitation in Wuhan are statistically analyzed. The results of statistical analysis show that from 1992 to 2021, the maximum hourly precipitation range of Wuhan City is 22.1mm-98.6mm, the maximum hourly precipitation is 98.6mm, the maximum continuous 3-hour precipitation range is 38.3-158.6mm, the maximum 3-hour cumulative precipitation is 158.6mm, the maximum 6-hour precipitation range is 46-221.2mm, and the maximum 6-hour cumulative precipitation is 221.2mm. The maximum 12-hour precipitation range is 62.4-276.7mm, the maximum 12-hour cumulative rainfall is 276.7 mm, the maximum 24-hour precipitation range is 70-293.3mm, the maximum 24-hour precipitation range is 293.3 mm, and the maximum continuous hourly precipitation range in Wuhan is 57.1-280mm.

7. Analysis of Return Period of Precipitation in Different Ages

The problem of extreme precipitation belongs to small probability events and belongs to the category of extreme value theory. In recent years, a variety of extreme value distribution models have been used to study extreme precipitation, flood and river runoff, and a variety of return period estimation methods have been derived. In general, the random variable X obeys the normal distribution. The extreme value is the maximum or minimum value selected from the random sequence, using $M_m = \max(x_1, x_2, \ldots, x_n)$, $M_n = \min(x_1, x_2, \ldots, x_n)$. The maximum and minimum values of n random variables are represented respectively, and their probability distribution characteristics can be fitted by the generalized extreme value model (GEV). There are extreme values in different aging precipitation, so they can also be fitted by GEV model. The distribution function of GEV model can be expressed as follows:

$$\mathrm{F(x)} = \exp\left[-\left(1 + \frac{\varepsilon(x-\mu)}{\sigma}\right)^{-\frac{1}{\varepsilon}}\right] \qquad 1 + \frac{\varepsilon(x-\mu)}{\sigma} > 0 \qquad (1)$$

Where ε, μ and σ are shape parameters, position parameters and scale parameters, respectively. When the shape parameters take different values, three different extremely behaviors are corresponding.

The parameters of GEV distribution can be estimated by moment method, maximum likelihood method, Gumbel method, probability weighting method and so on. Because the maximum likelihood method is easy to adapt to complex models and the effect of parameter estimation is quite accurate, this paper uses the maximum likelihood method to estimate the model parameters. After the parameters are determined, given the return period T, the annual extreme precipitation of T is

$$R_T = \mu - \frac{\sigma}{\varepsilon}\ln\left(1-(-lnp)^{-\varepsilon}\right) \qquad (2)$$

In the formula: R_T is the maximum hourly precipitation corresponding to the T-year recurrence period, and p is the probability corresponding to the return period.

In order to better understand the influence of short-duration heavy precipitation on waterlogging in Wuhan, based on the statistical analysis results of the previous conclusion, according to Gumbel extreme value I distribution method, the maximum hourly precipitation, maximum 3h precipitation, maximum 6h precipitation, maximum 12h precipitation, maximum 24h precipitation, maximum continuous hourly precipitation, maximum daily precipitation and maximum continuous daily precipitation are fitted, and the values of different recurrence periods are estimated. Table 2 and figure 4(a)-4(f) show the maximum hourly precipitation, maximum 3h precipitation, maximum 6h precipitation, maximum 12h precipitation, maximum 24h precipitation, maximum continuous hourly precipitation

Table 2. precipitation with different aging characteristics under different return periods.
(unit: mm)

Return period	1a	5a	10a	20a	30a	50a	100a	200a	500a
Max pre-1h	26	61.6	76.8	92.2	101.4	112.4	127.7	143	163.3
Max pre-3h	43.8	98.6	122.2	145.8	160.0	177.0	200.7	224.3	255.5
Max pre-6h	57.3	128.6	159.3	190.0	208.4	230.6	261.3	292.0	332.5
Max pre-12h	68	155.4	193.0	230.6	253.2	280.4	318.0	355.6	405.4
Max pre-24h	82	176.5	217.2	257.9	282.3	311.7	352.4	393.1	446.9

(a)

(b)

(c)

(d)

(e)   (f)
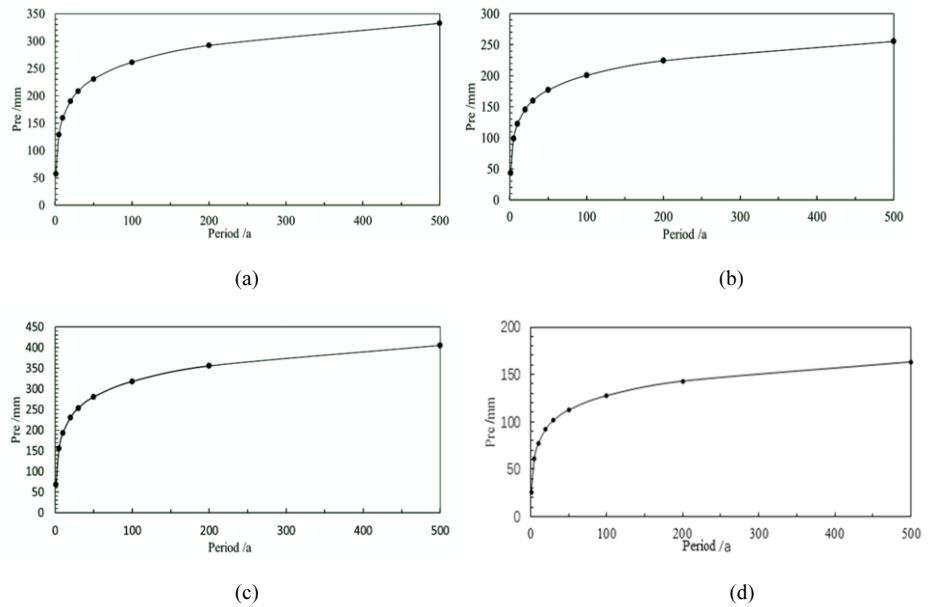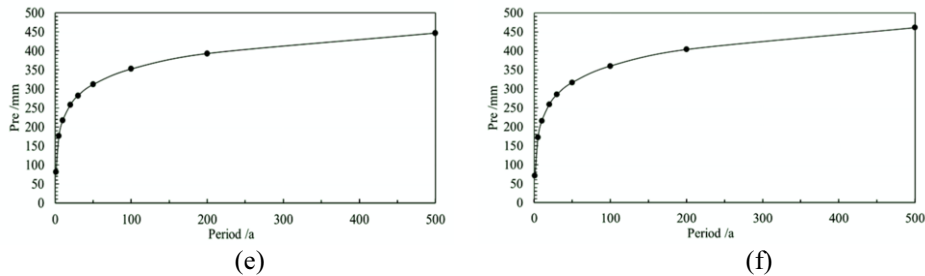
Fig.4 (a) return period distribution curve of maximum hourly precipitation in Wuhan; (b) return period distribution curve of maximum 3-hour precipitation in Wuhan; (c) return period distribution curve of maximum 6-hour precipitation in Wuhan; (d) return period distribution curve of maximum 12-hour precipitation in Wuhan; (e) return period distribution curve of maximum 24-hour precipitation in Wuhan; (f) return period distribution curve of maximum continuous hourly precipitation in Wuhan;

8. Conclusion

Based on the measured data of maximum one-hour rainfall from six representative rainfall stations in Wuhan from 1992 to 2021, the variation law, characteristic analysis and return period of different aging precipitation in Wuhan city in the past 30 years are analyzed. The results show that:

1) The average annual precipitation in Wuhan is 1290.4mm, and the maximum annual precipitation occurs in 2020. Although the annual precipitation days are increasing year by year, the annual rainstorm and the number of precipitation days above the rainstorm show a decreasing trend.

2) The precipitation in Wuhan is mainly concentrated in spring (March-May) and summer (June-August), with the most in summer, the average precipitation in spring is 345.2mm, the average precipitation in summer is 420.6mm, the average precipitation in autumn is 224.1mm, and the average precipitation in winter is 151.9mm.

3) The monthly precipitation in Wuhan is mainly concentrated in July, and the average annual precipitation in July is 235.6mm. The lowest precipitation is 29.4mm in December. The maximum monthly precipitation of many years appeared in July 1998, reaching 758.4mm.

4) Based on the parameters of GEV distribution, the maximum hourly precipitation, maximum 3h precipitation, maximum 6h precipitation, maximum 12h precipitation, maximum 24h precipitation, maximum continuous hourly precipitation, maximum daily precipitation and maximum continuous daily precipitation are fitted, and the values of different recurrence periods are estimated.

Reference

[1] Wang H, Wang XM, Jiang YY, et al. Spatio-Temporal Distribution and Environmental Parameters of Short-Time Severe Precipitation in the Chengde Mountains in Summer. Meteor Mon. 2021;47(12):1469-1483.
[2] Wang J, Zhang JG, Wu T, et al. MCS classification and characteristic analyses of extreme short time severe rainfall in Hubei Province. Meteor Mon. 2019;45(7):931-944.

[3] Dong XG, Gu WZ, Qiu C, et al. Spatio temporal distribution characteristics of hourly precipitation in Shandong Province in flood season. Meteor Mon. 2018;44(8):1063-1072.

[4] Wang BY, Zhao LN, Gong YF, et al. Characteristics of temporal pattern and return period of short-duration rainfall at Beijing Observatory. Torrential Rain and Disasters. 2015;34(4): 302-308

[5] Li R, Liu XW, Wei D, et al. Refined characteristics of precipitation in Lanzhou based on regional automatic weather stations data. Journal of Arid Meteorology. 2022; 40(1): 55-61.

[6] Guo GF, Du LM, Xiao Y, et al. Spatio-temporal distribution characteristics of summer extreme precipitation in the Yangtze River Basin. Journal of Arid Meteorology. 2021;39(2): 235-243.

[7] Enfield D B, Mestas-Nunez A M, Trimble P J. The Atlantic Multidecadal oscillation and it's relation to rainfall and river flows in the continental U.S. Geophysical Research Letters. 2001;28(10):2077-2080.

[8] Feng S, Hu Q. How the North Atlantic Multidecadal Oscillation may have influenced the Indian summer monsoon during the past two millennia. Geophys Research Letters. 2008;35: L01707.

[9] Fu Q, Johanson C M, Wallace J M, et al. Enhanced mid-latitude tropospheric warming in satellite measurements. Science. 2006;312(5777):1179-1179.

[10] Cheng D, Chen ZH. Evolution characteristics of rainstorm hyetograph in Yichang of Hubei Province. Journal of Arid Meteorology. 2017;35(2):225-231.

Three-Dimensional Simulation of the Effect of Operating Conditions on the Performance of the Air Ejector

Lifu HAN [a,1] and Daoqi LIU [b]

[a] *Hetao College, Bayannur Inner Mongolia 015000, China*
[b] *Department of Engineering Mechanics, Inner Mongolia University of Technology, Hohhot 010051, China*

Abstract. Temperature and pressure as two important working conditions of the air ejector are very important to its working performance. Taking the air ejector installed in a power plant as an example, and using ANSYS-FLUENT software, the three-dimensional simulation of the operation of the air ejector under different pressure and temperature conditions is carried out, and the relations between pressure, temperature, inlet gas flow rate and ejection coefficient are given. The results show that the working conditions of pressure and temperature have some influence on the performance of the air ejector. It is important to control the working conditions of the air ejector.

Keywords. Air ejector, ANSYS-FLUENT, Three-Dimensional numerical simulation, Vacuum pressure, Ejection coefficient

1. Introduction

At present, the water-ring vacuum pump is often used by thermal power plants to extract the non-condensable gas in the condenser, thus keeping the required vacuum pressure in the condenser, usually about 10KPa, but under this working condition, the vacuum pump is prone to cavitation and vibration, the cavitation will aggravate the damage and fracture of the blades in the pump, which will reduce the reliability of the unit operation. For example, before adding the air ejector, the cavitation of the unit is obvious, the vibration of the pump body is big, and the crack of the pump impeller occurs, During the two-year operation of the units in Sanmenxia Thermal Power Plant, 7 out of 9 vacuum pumps had blade fracture accidents, and 3 blade fracture accidents occurred in Guohua quasi-power plant in the past two years, Since Datang Hebei Matou and Guodian civil rights and other thermal power plants put into operation, the vacuum pump blades have broken many times [1]. A large number of experimental studies show that the modification of the water-ring vacuum pump with an air ejector can not only eliminate the cavitation of the

---

water-ring vacuum pump, but also reduce the vibration and noise pollution, moreover, it can reduce the vacuum pressure of the condenser and save a lot of operating costs. Therefore, this technical transformation has been adopted by many thermal power plants in our country. However, because this technology is not mature and perfect enough, once the first test fails, the cost of trial and error is doubled because the theory requires computational fluid dynamics knowledge, the equations of mass, momentum, energy and turbulence of CFD are all partial differential equation [2]. It is very difficult to calculate and solve these equations by hand. The numerical solutions of simplified one-dimensional, two-dimensional and two-dimensional axisymmetric models sometimes have large errors, and the cost of field test is too expensive [3].

2. Three-Dimensional Modeling and Analysis of Air Ejector

2.1. Model Entity and Model Diagram

The entity model of air ejector in a power plant is shown in Figure 1, and geometric model is shown in Figure 2.

Figure 1. Schematic diagram of air ejector.

The working principle of air ejector: First start the water ring vacuum pump, make the pressure difference between the air inlet and the air outlet of the nozzle, the air (A-Working gas) can enter the pump from the nozzle and be accelerated through the nozzle contraction section, at the throat of the nozzle, the air flow can reach the sound speed, and at the expansion section of the nozzle, it can be further accelerated to the supersonic speed. A high-speed jet is injected into the ejection chamber, causing the pressure in the ejection chamber to be lower than that in the evacuated container (Condenser) , and therefore, the pumped gas (B-Ejection gas) is drawn into the ejection chamber. Because the two air streams are mixing in the ejection chamber, the loss of momentum exchange causes the working air flow rate to slow down gradually and the velocity of the ejection gas to speed up gradually, the velocity gradually drops below the speed of sound, and then decreases further through the expansion section of the diffusion pipe, but the gas (C-Mixed gas) pressure continuously increases, reaches the exhaust pressure of the air ejector, Finally, through the water-ring vacuum pump to the mixed gas out of the pump, and then complete the suction, exhaust the whole process [4-6].
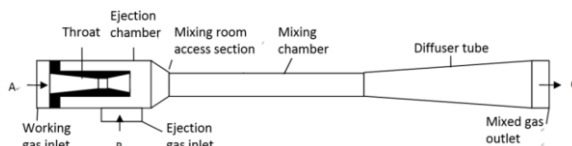
Figure 2. Geometric model of air ejector: A-working gas, B-ejection gas, C-mixed gas.

2.2. Building 3D Simulation Model

Using ANSYS-FLUENT building 3-D section drawing of air ejector, see figure 3 [7] .

Figure 3. 3-D model section drawing of air ejector along central axis XOY

2.3 Grid Partitioning and Generation

Select Tetrahedrons grid, Patch Independent algorithms, Set Min Size Limit to 1mm, set Relevance value to 100, and generate the grid with 513953 units, as shown in figure 4.
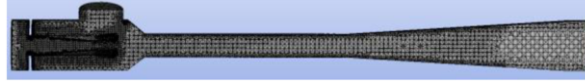
Figure 4. 3-D grid section drawing of air ejector along central axis XOY

3. Three-Dimensional Numerical Simulation Calculation and Result Analysis

3.1. Control Equation

3.1.1. Mass Conservation Equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w) = 0 \tag{1}$$

Where x, y and z are coordinates. u, v and w are velocity functions. ρ is density functions, and t is time.

3.1.2. Momentum Conservation Equations

$$\frac{\partial \rho u}{\partial t} + div(\rho u U) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + F_x \tag{2a}$$

$$\frac{\partial \rho v}{\partial t} + div(\rho v V) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + F_y \tag{2b}$$

$$\frac{\partial \rho w}{\partial t} + div(\rho w W) = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} + F_z \tag{2c}$$

Formula (2a) , (2b) , (2c) p is the pressure on the fluid microelement. U, V and W are velocity functions. $\tau_{ii}, \tau_{ij}, \tau_{ji}$ is the component of the viscosity stress τ on the surface of the microelement produced by the molecular viscosity action, F_x, F_y, F_z is the volume force on the microelement.

3.1.3. Conservation of Energy Equation

$$\frac{\partial(\rho T)}{\partial t} + \frac{\partial(\rho u T)}{\partial x} + \frac{\partial(\rho v T)}{\partial y} + \frac{\partial(\rho w T)}{\partial z} = \frac{\partial}{\partial x}\left(\frac{k}{c_p}\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{k}{c_p}\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(\frac{k}{c_p}\frac{\partial T}{\partial z}\right) + S_T \tag{3}$$

Among them: c_p is the specific heat capacity, T is the temperature, k is the fluid heat transfer coefficient, S_T is the fluid viscous dissipation rate.

3.2. The Parameter Setting

Model is k-omega(2 eqn)SST, Materials is ideal-gas, Turbulent Dissipation Rate and Energy are Sencend Order Upwind, the inlet of working gas and ejection gas is pressure-inlet, the outlet of mixed gas is pressure-outlet, Turbulent Intensity(%)is set to 2, the rest is the default [8-10].

3.3. Numerical Simulation and Analysis

The control variable method is used below to calculate the inlet flow rate and ejection coefficient of working gas and ejection gas under different pressure and temperature conditions respectively, where the ejection coefficient is equal to the ratio of the ejection gas flow rate to the working gas flow rate.
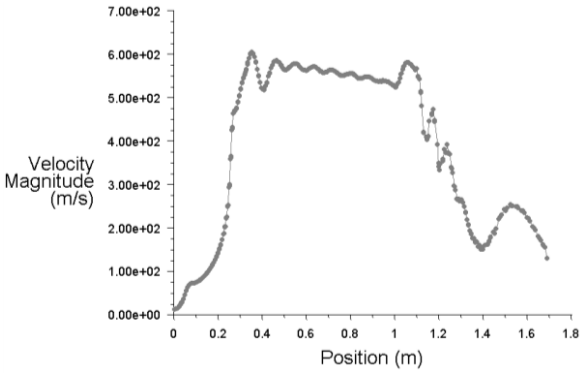
Figure 5. velocity curves of points on the axis
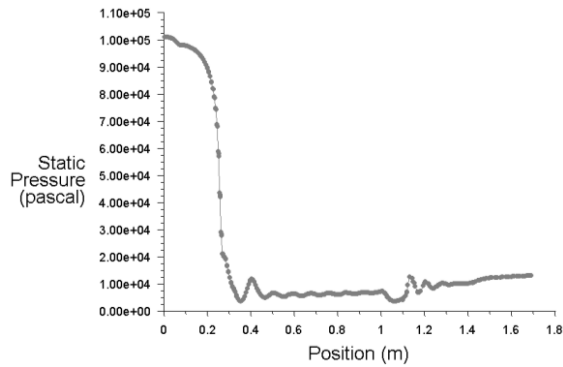
Figure 6. pressure curves of points on the axis
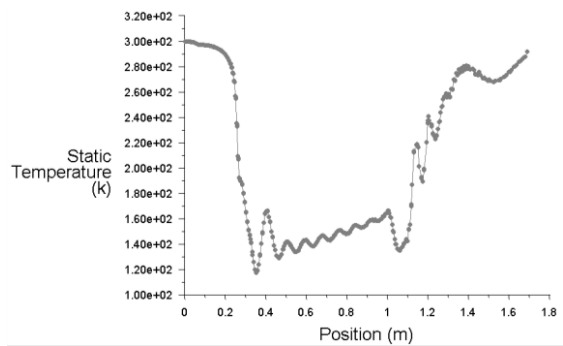
Figure 7. temperature curves of points on the axis

When the inlet and outlet pressure and temperature are constant, the velocity, pressure and temperature curves of points on the axis are given in figures 5, 6 and 7 respectively，the velocity, pressure and temperature clouds of the XOY section are given in figures 8, 9 and 10 .
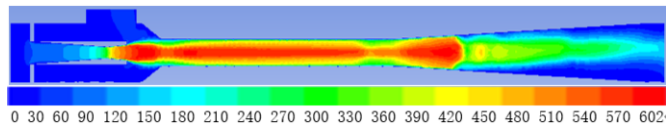
Figure 8. XOY cross-sectional velocity cloud (m/s)
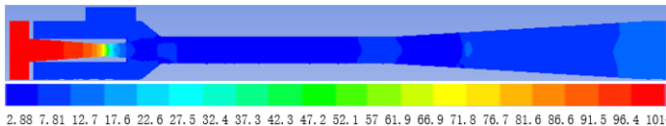
Figure 9. XOY cross-sectional pressure cloud (KPa)
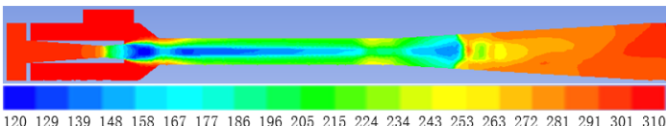
Figure 10. XOY cross-sectional temperature cloud (°C)

3.3.1 Influence of Pressure Condition on Working Performance

(1) Influence of inlet pressure of ejection gas

The outlet pressure of mixed gas is set at 13300Pa, the temperature is set at 310K, the inlet pressure of working gas is set at 101325Pa, the temperature is set at 300K, the ejection gas inlet temperature is set at 310K, When the inlet pressures is 4000 Pa, 5000 Pa, 6000 Pa, 7000 Pa, 8000 Pa, 9000 Pa, 1000Pa, 11000 Pa, 12000 Pa, 13000 Pa, 14000 Pa, 15000 Pa, 16000 Pa, 17000 Pa or 18000 Pa to analyze and calculate, and the relation curves of figures 11(a) and (b) are drawn, the vacuum pressure is numerically equal to the ejection gas inlet pressures.

As can be seen from figure 11(a) and (b), when the inlet pressure of the ejection gas varies from 4 KPa to 18 KPa, the working gas flow rate remains basically constant. The

ejection gas flow rate and ejection coefficient increase with the vacuum pressure increasing.

(a)   (b)
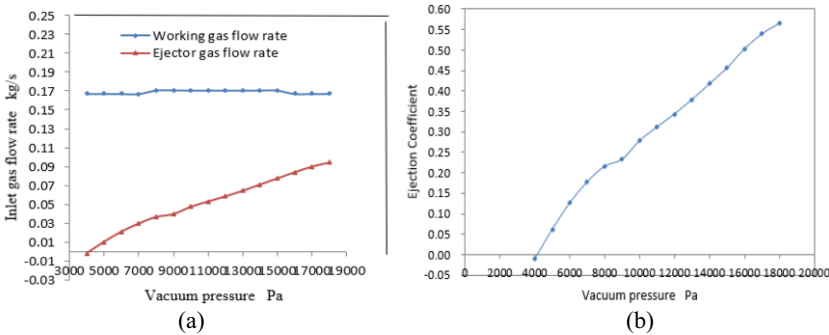
Figure 11. Curve of vacuum pressure with inlet gas flow rate and ejection coefficient

(2) Influence of inlet pressure of working gas

(a)   (b)
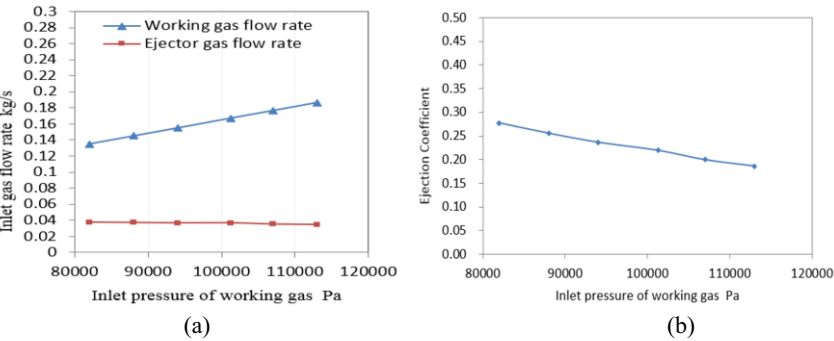
Figure 12. The inlet pressure of working gas versus inlet gas flow rate curves

The inlet pressure and the temperature of mixed gas is set at 13300Pa, 310K, the inlet temperature of working gas is 300K, the inlet pressure and the temperature of ejection gas is set at 8000Pa, 310K. When the inlet pressures of the working gas is 82000Pa, 88000Pa, 94000Pa, 101325Pa or 107000 Pa to calculate the ejection gas flow rate and to draw the relation curves of figure 12(a) and (b).

From figure 12(a) and (b) , it can be seen that when the inlet pressure of working gas increases from 82 KPa to 113 KPa, the ejecting gas flow rate remains constant, the working gas flow rate increases and ejecting coefficient decreases.

(3) Influence of mixed gas outlet pressure

Set the inlet pressure of the working gas to 101325Pa, the inlet temperature of the working gas to 300K, the inlet temperature of the ejection gas to 8000Pa, the inlet temperature of the ejection gas to 310K. When the outlet pressures of mixed gas is 9000Pa, 10000Pa, 11000Pa, 12000Pa, 13300Pa, 14000Pa, 15000Pa, 16000Pa, 17000Pa, 18000Pa, 19000Pa, 20000Pa, 21000Pa, 22000Pa, 23000Pa, 24000Pa, 25000Pa or 26000Pa, the ejection gas flow rate are calculated. The relation curves of figure 13(a) and (b) were drawn.

As can be seen from figure 13(a) and (b) , when the outlet pressure of the mixed gas changes from 9 KPa to 24 KPa, the working gas flow rate and the ejection gas flow rate remains constant, but when the pressure of the mixed gas is higher than 24 KPa, the

working gas flow rate remains unchanged, however, the ejection gas flow rate and ejection coefficient will decrease rapidly.

(a)   (b)
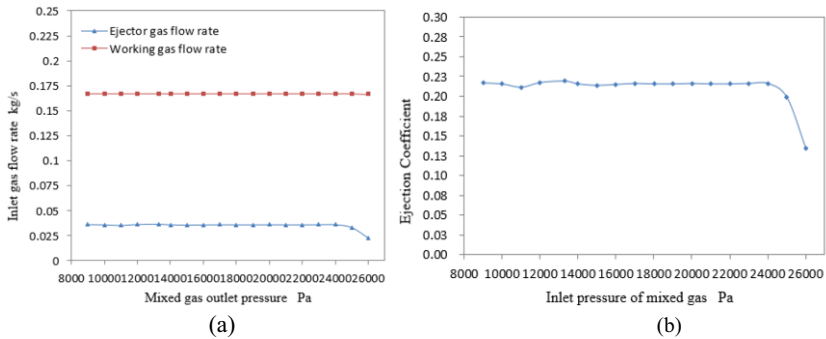
Figure 13. Relationship curve between outlet pressure and flow rate of mixed gas

3.3.2 Effect of Temperature Condition on Performance

Since the inlet of the ejection gas is connected with the condenser, the inlet temperature of the ejection gas, which has direct influence on the vacuum pressure and the ejection coefficient, is selected to study and analyze. The inlet pressure of the working gas is set at 101325Pa and the inlet temperature of the working gas is set at 300K, the inlet pressure of the ejection gas is 8000Pa, the outlet pressure of the mixed gas is 21000Pa and the outlet temperature of the mixed gas is 310K. The inlet flow rates corresponding to the inlet temperatures of the ejection gas are calculated at 285K, 290K, 295K, 300K, 305K and 310K respectively, the relation curves of figure 14(a) and (b) are plotted.

(a)   (b)
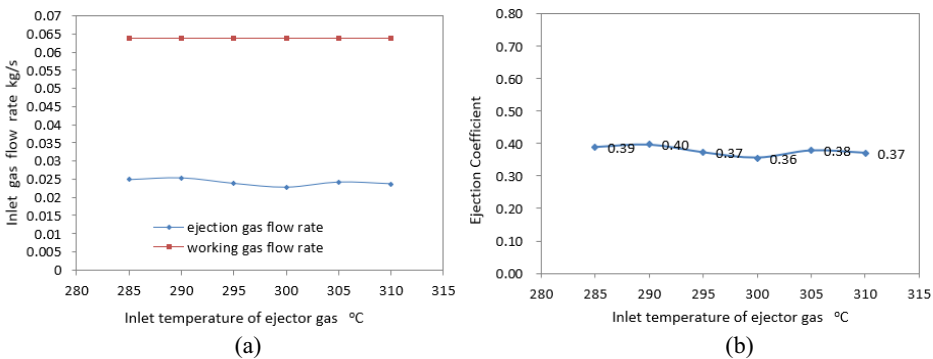
Figure 14. Relation curve between inlet temperature and inlet flow rate of ejecting gas

From the figure 14(a) and (b) , it can be seen that when the inlet temperature of the ejection gas changes in the range of 285K-310K, the working gas flow rate and the ejection gas flow rate keep constant, and the ejection coefficient basically keeps a certain value of 0.38.

4. Conclusion

When the structure parameters of the air ejection are fixed, the ejection gas flow rate and ejection coefficient will increase with the increase of the vacuum pressure. When the inlet pressure of the working gas changes in a certain range, the ejection coefficient will decrease with the increase of the inlet pressure of the working gas. When the inlet pressure of the mixed gas is higher than 24 KPa, the ejection gas flow rate will decrease suddenly, and the ejection coefficient will also decrease rapidly. The change of the inlet temperature of the ejection gas has little effect on the performance of the air ejector. In addition, when the outlet pressure of the mixed gas is limited in the range of 14 KPa to 24 KPa, the vacuum pressure of the condenser can be ensured, and it can effectively avoid cavitation damage and noise pollution of the water ring vacuum pump.

References

[1] Han L F, Liu D Q. Numerical Simulation Research on the performance of air ejector based on FLUENT. Journal of Inner Mongolia University of Technology (Natural Science Edition). 2009; (4): 297-301.

[2] Ruan Z Y. Three-dimensional numerical simulation and structure analysis of liquid ring pump ejector. South China University of Technology. 2010; 06:44-60.

[3] Ruslya E, Lu A, Charters W S, Ooi A. CFD analysis of ejector in a combined Ejector cooling system. International Journal of Refrigeration. 2005; (28):1092-1101

[4] Menter F R, Kuntz M and Langtry R Ten Years of Industrial Experience with the SST Turbulence Model. Turbulence, Heat and Transfer. 2014; 3(3):67-69.

[5] Hemidi A, Henry F, Leclaire S, Seynhaeve J, Bartosiewicz Y.CFD analysis of a supersonic air ejector. Part I: Experimental validation of single-phase and two-phase operation. Applied Thermal Engineering 2009; (29): 1523-1531.

[6] Hemidi A, Henry F, Leclaire S, Seynhaeve J, Bartosiewicz Y. CFD analysis of a supersonic air ejector. Part II: Relation between global operation and local flow features. Applied Thermal Engineering 2009; (29): 2990-2998.

[7] Liu C Z. ANSYS workbench 17.0 example of thermodynamic analysis exercise. China Machine Press. 2018; 05(first edition): 20-132.

[8] Ding X S, Liu B. Fluent 17.0 fluid simulation from introduction to master. Tsinghua University Press. 2018; 01(first edition):36-171.

[9] Mazzelli F, Little A B, Garimella S, Bartosie-wicz Y. Computational and experimental analysis of supersonic air ejector: Turbulence modeling and assessment of 3D effects. International Journal of Heat and Fluid Flow 2015; (56): 305-316.

[10] Sriveerakul T, Aphornratana S, Chunnanond K. Performance Prediction of Steam Ejector Using Computational Fluid Dynamics. International Journal of Thermal Sciences, 2007; 46:812-822.

Numerical Simulation Study of Dust Transport of Comprehensive Mining Working Surface

Liang WANG [a,c], Fengfeng LI [a,1], Yuyin GUO[b], Qingzhen LI[b], Tianming CHEN[a,c] and Jingjian WU[b,2]

[a] *School of Mechanical and Electronic Engineering, Shandong University of Science and Technology, Qingdao, China*
[b] *Shandong Ji Mine Luneng Coal Power Co., Ltd, China*
[c] *Qingdao Ecotek Intelligent Technology Co., Ltd, Qingdao, China*

Abstract. In order to study the wind flow field and dust transport law of the comprehensive mining work surface, taking the 21103 comprehensive mining working surface of Hulusu Coal Mine as the research object, SolidWorks was used to establish the comprehensive mining working surface model, and the comprehensive mining working surface under different inlet wind speed conditions was simulated and analyzed by Fluent. The results show that due to the existence of the high-speed wind flow belt, dust is mainly distributed near the downwind side working surface; when the inlet speed is $2.5m/s$, the dust mass concentration of the comprehensive mining working surface is low and it is not easy to cause secondary dust, which is the optimal inlet speed; the dust distribution within $10\ m$ of the downwind side of the shearer is the most, which is the key area of dust prevention and control.

Keywords. Fluent simulation, wind flow field, high-speed wind flow band, transport law

1. Introduction

In the process of mining coal will inevitably produce a large amount of dust [1][2], dust concentration is too high when prone to explosion, seriously threatening the life of workers, and the comprehensive mining work surface is one of the most important dust production sites [3][4][5], the mass concentration of dust can reach $2000mg/m^3$, has been far higher than the quality concentration standard of safe production [6][7]. With the further development of mining machinery, improving dust reduction efficiency and solving the harm caused by dust is the top priority of safe production [8]. At present, the comprehensive mining work surface mainly uses spray dust reduction, and there is less research on ventilation and dust reduction, mainly because the situation in the roadway is more complicated, and it is more difficult to change the ventilation amount and other

---

[1] Corresponding author: Fengfeng LI, Shandong University of Science and Technology Campus, Qingdao, Shandong Province, E-mail:321935581@qq.com.
[2] Corresponding author: Jingjian WU, No.2299 Chongwen Avenue, High-tech Zone, Jining City, Shandong Province, Tel: 0537-2379087, E-mail: wujingjian52@163.com.

conditions, so it is impossible to obtain the flow field and the movement law of dust in the roadway through field experiments [9]. Therefore, this paper conducts numerical simulation of the comprehensive mining working surface model through Fluent simulation software [10], mainly to study the influence of inlet wind speed on the dust movement law in the roadway under different conditions, and to obtain the dust distribution in different locations in the roadway [11], so as to find out the key areas of dust prevention.

2. Comprehensive Mining Work Surface Dust Transport Model

2.1. Physical Model and Meshing

In this paper, taking the site situation of the 21103 comprehensive mining surface of Cucurbitasin Coal Mine as the background of the study, ignoring other equipment with small influencing factors in the roadway, only considering the hydraulic support and shearer, using the 3D modeling software Solidworks to establish a simplified physical model, as shown in Figure 1. Mesh is used to mesh the comprehensive mining work surface model, which is divided into tetrahedral meshes with high degree of conformity and automation, and the average mesh quality of the model is 0.83, the number of nodes is 295826, and the number of elements is 1526924. The size of the working surface is 50 m, 4 m, and 4 m, the shearer is arranged at 10 m from the air inlet, the hydraulic support is simplified to a cylinder with a radius of 0.2 m, and it is arranged sequentially along the air inlet to the outlet of the comprehensive mining work surface, and the distance between each hydraulic support is 2 m.
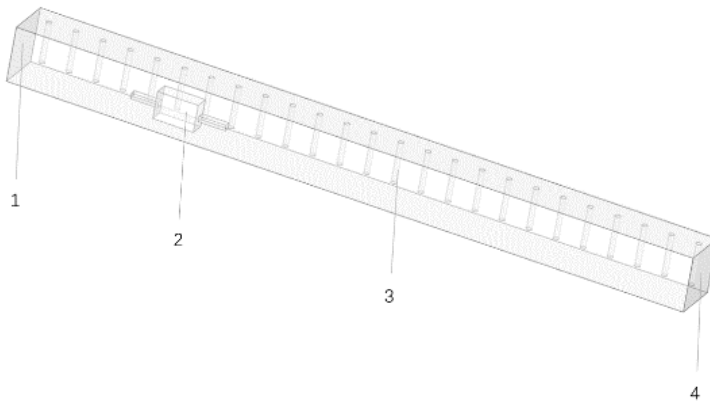
Figure 1. Simplified physical model of the comprehensive mining work surface: 1- Air inlet; 2- Shearer; 3- Hydraulic support; 4- Output.

2.2. Mathematical Models

In order to better study the movement law of dust, combined with Euler's equation and constructing a Lagrange mathematical model, the trajectory of dust is obtained.

1)Continuous equations

$$\frac{\partial \rho}{\partial t} + v \frac{\partial \rho}{\partial x} = K \cdot \frac{\partial^2 \rho}{\partial^2 x} \tag{1}$$

wherein: ρ is the average mass concentration of dust, v is the average speed, K is the composite diffusion coefficient, t is the diffusion time.

2) Equation of motion of dust in air

$$m_P \frac{dv}{dt} = \frac{\pi}{6} d_P^3 (\rho_P - \rho_g) - C_P \frac{\pi}{4} d_P^2 \frac{v^2}{2} \rho_g \tag{2}$$

wherein: m_P is the total mass of dust, v is the relative speed of dust and air, t is the time, ρ_P is the dust density, ρ_g is the gas density, d_P is the particle size of the dust,g is acceleration for gravity, C_P is the resistance coefficient.

2.3. Primary boundary condition settings

After the partitioned mesh is updated and imported into Fluent, some parameters need to be set in Fluent before solving, and the main parameter settings are shown in Table 1.

Table 1. Main parameter settings

type	Parameter settings
Air intake	Speed entry
outlet	Speed exit
Speed entry	1.5 m/s
Speed exit	Outflow
Solver	SIMPLE
Time properties	Steady-state computation
Turbulence intensity	5%
Hydraulic diameter	0.4m
Coupled to each other	on
Injection Type	Surface
Material	Coal-hv
Min Diameter	1μm
Max Diameter	100μm
Mid Diameter	10μm

3. Numerical calculation results analysis

3.1. Distribution of wind flow fields on the comprehensive mining work surface

Wind flow is an important factor affecting the diffusion of dust in the roadway, and the analysis and study of the distribution of the wind flow field of the comprehensive mining work surface is conducive to analyzing the movement law of dust. After the parameter setting is completed, the model is simulated with an initial wind speed of 1.5 m/s, and the distribution of the flow field at different positions of the comprehensive mining working surface is obtained, which is 1 m and 1.5 m from the ground height and 0.6 m and 1.5 m parallel to the roadway length, respectively, as shown in Figure 2-5.
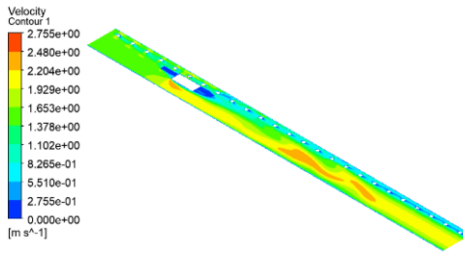
Figure 2. The distribution of the current field at a height of 1 m from the ground.
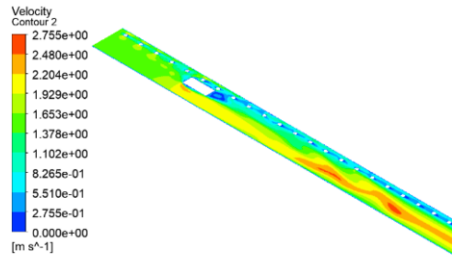
Figure 3. The distribution of the current field at a height of 1.5 m above the ground.
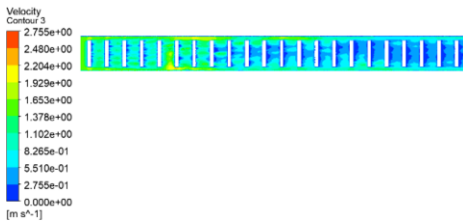
Figure 4. The distribution of the current field is 0.6m from the comprehensive mining surface.
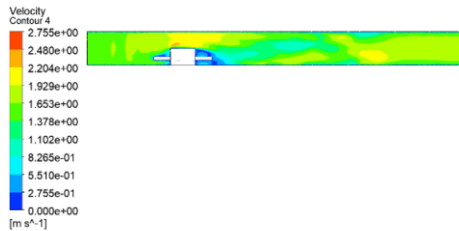
Figure 5. The distribution of the current field is 1.5 m from the comprehensive mining surface.

As can be seen from Figures 2-5, the wind flow enters from the entrance of the roadway at 1.5m/s, the wind speed gradually increases in the roadway, and the closer to the center of the roadway, the greater the wind speed, the maximum wind speed in the local position can reach 2.75 m/s, and near the shearer, due to the obstruction of the wind flow, a high-speed turbulence area is formed around the shearer, the average wind speed reaches 2.1m/s, which affects the shearer to the roadway exit to form a wind flow belt, and the average wind speed reaches 2.2 m/s. When the air flow flows through the working surface, due to the obstruction of the working face of the wind flow, a laminar flow will be formed, resulting in a small air flow speed in contact with the working surface, and the hydraulic support is affected by the low wind speed near the hydraulic support due to its proximity to the working surface.

3.2. Distribution of dust mass concentration on the working surface of comprehensive mining

After the continuous phase simulation is completed to obtain the flow field distribution, continue with the initial wind speed of 1.5 m/s unchanged, open the discrete phase model, set the injection source and spray conditions, simulate the model, and obtain the dust mass concentration distribution of the working surface of different heights, which are 0.5 m, 1 m, 1.5 m and 2 m from the ground height, respectively, as shown in Figures 6-9.
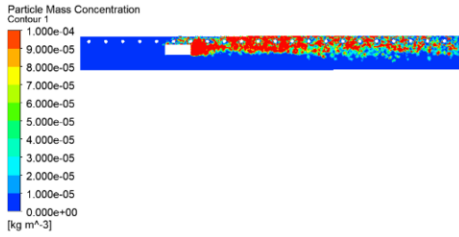
Figure 6. Dust mass concentration distribution 0.5 m above ground level.
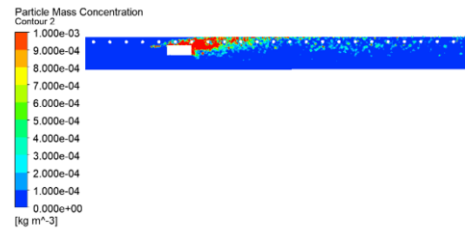
Figure 7. Dust mass concentration distribution 1 m above ground level.
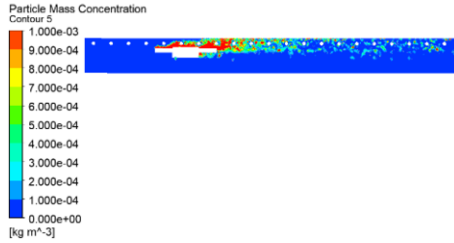
Figure 8. Dust mass concentration distribution 1.5 m above ground level.
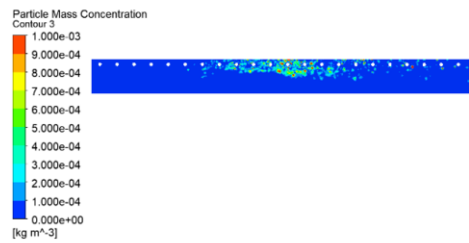
Figure 9. Dust mass concentration distribution 2 m above ground level.

As can be seen from Figures 6-9, the farther away from the ground the dust mass concentration is lower, the height from the ground reaches more than 2 m, the dust content in the roadway is significantly lower, and the dust mass concentration near the shearer due to the existence of dust sources, so the dust mass concentration near the shearer is the highest, which can reach 1000 mg/m^3, and the wind side of the shearer due to the air inlet, the dust will be affected by the wind after the dust generation, and then spread in the direction of the air outlet, so the dust mass concentration in the wind side roadway on the shearer is less than 100 mg/m^3. When the dust generated at the dust source spreads in the direction of the air outlet, due to a high-speed wind flow belt formed in the center of the roadway, the wind speed in the roadway of the same height is low, which in turn makes it difficult for the dust to spread to the center of the roadway, making the dust mass concentration near the comprehensive mining work surface high.

3.3. Effect of wind speed on the mass concentration of dust on the working surface of comprehensive mining

The height at which people inhale dust in the roadway is around 1.6 m, so the height of 1.6 m is selected for study. Keep other parameters unchanged, only change the size of the inlet wind speed, in order to study the effect of different inlet wind speed on the mass concentration of the working surface of the comprehensive mining, so as to find the optimal inlet wind speed, respectively, the inlet wind speed of 1.5m/s, 2 m/s, 2.5m/s and 3m/s to simulate, respectively, to obtain the dust mass concentration of 1.6 m from the ground height after adding dust ventilation 30 s, as shown in Figures 10-13.
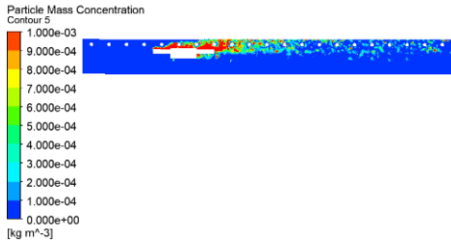
Figure 10. Dust mass concentration distribution at inlet wind speed of 1.5 m/s.
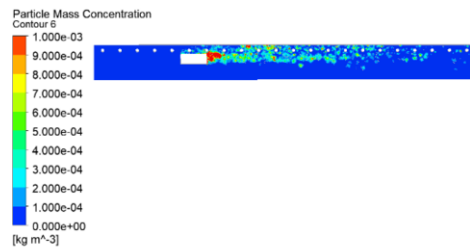
Figure 11. Dust mass concentration distribution at inlet wind speed of 2 m/s.
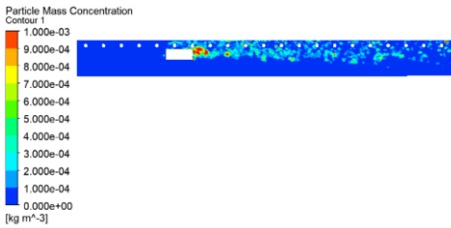
Figure 12. Dust mass concentration distribution at inlet wind speed of 2.5 m/s.
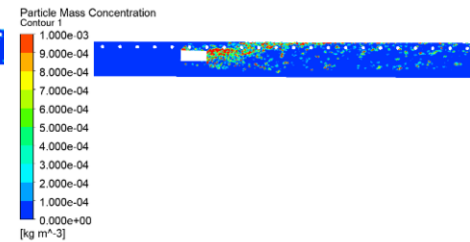
Figure 13. Dust mass concentration distribution at inlet wind speed of 3 m/s.

As can be seen from Figures 10-13, with the increase of the inlet wind speed, the average mass concentration of dust in the roadway appears to decrease first and then increase the trend, within 1.5-2.5m/s, the dust concentration decreases with the increase of wind speed, which is due to the increase of wind speed can quickly take away the dust, reduce the dust concentration, when the wind speed reaches 3m/s, the dust concentration in the roadway turns to increase, which is due to the excessive wind speed, resulting in the difficulty of settling the dust, and the dust that has settled appears secondary dust phenomenon. Therefore, when the inlet wind speed is 2.5 m/s, it is conducive to dust removal and is not easy to raise dust, which is the optimal inlet wind speed. At the same time, it can be seen from Figures 10-13 that the dust mass concentration within 10m on the right side of the shearer has been very high, and the average concentration is maintained at about 600 mg/m^3, which belongs to the key dust suppression area.

4. Conclusion

(1) From the entrance of the roadway to the exit of the roadway, the wind speed gradually increases, the closer to the center of the roadway, the greater the wind speed, and due to the influence of the high-speed turbulence area, the shearer to the center of the roadway outlet forms a high-speed air flow belt, and the working surface near the laminar flow, resulting in low wind flow near the hydraulic support.

(2) The greater the height from the ground in the roadway, the lower the dust mass concentration, and the dust in the roadway is difficult to spread on the upwind side, and it is concentrated on the downwind side, due to the influence of the high-speed wind flow belt in the roadway, the dust distribution in the roadway is mainly concentrated near the

downwind side working surface.

(3) When the inlet wind speed is 2.5 m / s, the average mass concentration of dust in the roadway is low, it is not easy to cause secondary dust, which is the optimal inlet wind speed, and the downwind side of the shearer belongs to the key area of dust prevention and control within 10 m, and dust reduction should be taken in time to prevent dust from staying in the air for too long.

References

[1] Cheng Genyin, Hou Jiayin, Si Junhong, Lianheng, Deng Pengfei, Li Lin. Numerical simulation study on dust and wind flow distribution of comprehensive mining working surface[J]. Journal of North China Institute of Science and Technology, 2020, 17(06):29-34.

[2] Wang Liang, Shi Jifei, Guo Weizhou, et al. Simulation study on the structure of mining swirl nozzle based on CFD[J]. Coal Technology, 2021,40(08):193-195.

[3] Zhang Xinhai, Shang Zhizhou, Feng Zhen, Liu Yangjun. Numerical simulation of the distribution of dust in the wind flow-respiration belt of the working surface of large-scale high comprehensive mining[J]. Journal of Safety and Environment, 2021, 21(02).

[4] Xu Qingyun, Bai Zhiyun, Li Jinbo. Study on the distribution law of dust source wind flow-dust on the working surface of large mining and high comprehensive mining[J]. Mining safety and environmental protection, 2020, 47(05).

[5] He Ning, Zhang Liangliang. Numerical simulation study on dust transport law of comprehensive mining working surface[J]. Journal of Longyan University, 2020, 38(05).

[6] Su Shilong, Hao Yongjiang. Distribution of PM5 and PM10 dust on the working surface of large-scale mining and high comprehensive mining[J]. Coal mine safety, 2020, 51(07).

[7] Kong Yang, Pang Haosheng, Song Shuzheng, Meng Qunzhi. Numerical simulation study on the law of dust diffusion pollution on comprehensive mining working surface[J]. Coal mine safety, 2020, 51(06).

[8] Song Shuzheng, Qu Yalong, Jing Bin. Exploration on the law of wind flow-dust escape on the working surface of FLUENT comprehensive mining[J]. Mining research and development, 2019, 39(11).

[9] Li Dejun, JIA Baoshan, Wang Junming. Study on dust detection and hydrophilic characteristics of comprehensive mining surface in Hanjiawa Coal Mine[J]. Energy Technology and Management, 2019, 44(06).

[10] Jia Chaobin. A brief analysis of the dust prevention and control technology of the working surface of the comprehensive mining of coal mines[J]. Contemporary chemical research, 2019, (15).

[11] You Chunlin. Research on dust prevention and control technology of comprehensive mining working surface[J]. Coal Economy of Inner Mongolia. 2019, (16).

CFD-Based Spherical Fiber Filter Structure Performance Simulation Research

Liang WANG[a,b], Xunyuan ZHAO[a,1], Jingjian WU [c], Yuyang SUN[a], Mingchao WU[a] ,Kai ZHANG[d,2]

[a]*School of Mechanical and Electronic Engineering, Shandong University of Science and Technology, China*
[b]*Qingdao Ecotek Intelligent Technology Co., Ltd, China*
[c]*Shandong Ji mine Luneng Coal Power Co., Ltd, China*
[d]*Guoneng Yili Energy Co.,Ltd, China*

Abstract. Spherical fiber filter is an important water purification device under the coal mines. When the thickness and porosity of its internal filter layer changes, the filtering performance will also change. In order to study the effects of the filtration performance of the porosity and the thickness of the lower filter layer, this article uses SolidWorks for modeling and ANSYS CFD (Computational Fluid Dynamics) numerical simulation technology for simulation analysis. The conclusion is obtained through simulation research: The filter layer porosity above the fiber filter is 0.7, the porosity of the filter layer below is 0.6, And when the filter layer thickness of the porosity of 0.6 accounts for 30% of the thickness of the entire filter layer, the filtering performance is the best. At this time, the pressure drop in the filter will not be too large, causing too much energy loss. And the filtration speed will not be too small and cause too low efficiency.

Keywords. spherical fiber filter; Fluent; filter layer thickness; porosity

1. Introduction

In water treatment filtering technology, fiber filtering technology has gradually been valued as an emerging technology, and is widely used in the water treatment of coal mines [1-2]. In 2013, Meng et al. used the Fluent fluid analysis software to simulate the porous medium to obtain the length of the porous medium and the fluid pressure drop and the linear relationship of the flow rate [3]. In 2015, Li and others used CFD software to simulate the fiber filter, optimized the filter model, and further studied the effects of filtering speed and pressure drop on the filter performance [4]. Fiber filter is the core part of the filter device of the water purification station [5-7], which plays a key role in the filtering effect and efficiency of the mine water [8-9]. The spherical fiber filter is filled with modified fiber ball filter material as its filter material [10], which is fixed with

porous plate. This filter material porosity is high and the distribution is uniform. The porosity of the upper filter layer in the fiber filter is large, and the porosity of the lower filter layer is small [11], which forms an ideal filtering state with a loose above and tight below [12]. The large granules are filtered by the upper fiber and the small particles are filtered by the lower layer [13].

Based on the method and ideas of the fluid numerical simulation, this article studies the effects of the porosity and filter layer thickness through Fluent simulation software to find the best porosity and filter layer thickness on the effects of filtration pressure and filtration speed to improve the filtering performance of the device, reduce energy consumption, and extend the service life.

2. Fiber filter model establishment

2.1 Establishment of mathematical models

Fluid flow follows the laws of conservation and dynamics conservation, and can be described by the following equations.

1) Quality Conservation equation

$$\frac{\partial \rho_f}{\partial t} + \nabla \cdot (\rho_f v) = 0 \qquad (1)$$

2) Constant conservation equation

$$\frac{\partial \rho_f v}{\partial t} + \nabla \cdot (\rho_f v - \tau_f) = f_f \qquad (2)$$

wherein: f_f is the volume force component, t is time, ρ_f is fluid density, V is the fluid velocity component. τ_f is the shear force tensor.

τ_f can be expressed as

$$\tau_f = (-p + \mu \nabla \cdot v)I + 2\mu e \qquad (3)$$

$$e = \frac{1}{2}(\nabla v + \nabla v^t) \qquad (4)$$

wherein: P is fluid pressure, μ is Dynamic viscosity, I is moment of inertia of section, e is Velocity stress tensor.

2.2 Physical model establishment

SolidWorks software is used to establish the model. The upper and lower ends are inlet and outlet pipes with a diameter of 30 mm. The middle spherical structure is filled with fiber filter material with a diameter of 1000 mm. The lower cylindrical area is the outlet transition area with a diameter of 300 mm and a length of 350 mm. The interior is hollow and the wall thickness is 2 mm, as shown in Figure 1.Then mesh it in the Mesh module of Worhbench, set the mesh size to 10 mm in the mesh module, and use the automatic generation method to generate tetrahedral mesh. The number of generated mesh units is 167980 and the number of nodes is 88380, as shown in Figure 2. Dividing the grid can divide the model into multiple simple individuals, and the individuals are interconnected

and restrict each other. By performing finite element analysis of multiple individual units, complex analysis is simplified.
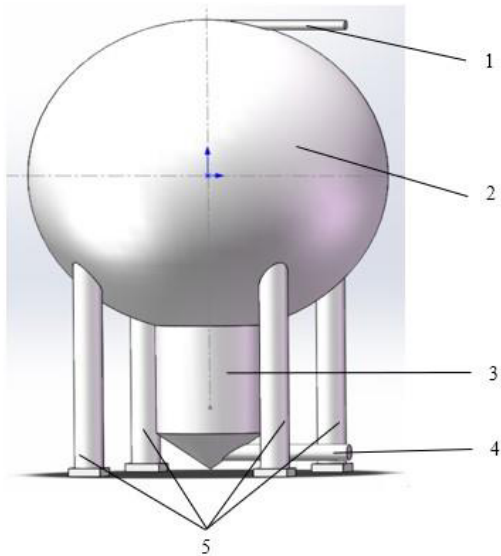
Figure 1. (1) Import 2.Filter layer 3.Transition zone 4.Exit 5.Pillar)
Model of spherical fiber filter
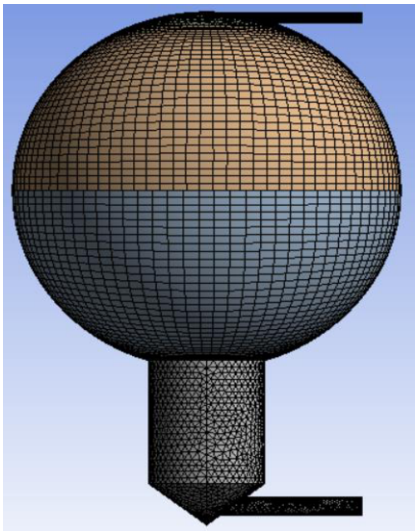
Figure 2 . Grid division diagram

3. Determination of parameters

The viscosity resistance coefficient $\frac{1}{\alpha}$ and inertial resistance coefficient C_2 are the

main parameters calculated in the porous media model in Fluent. The calculation formula is:

$$D_u = \frac{1}{\alpha} = \frac{|\Delta P_1|}{L\mu\, v_\infty} \qquad (5)$$

$$C_2 = \frac{3.5}{\varepsilon^2}\sqrt{\frac{|\Delta P_1|\varepsilon}{150 L\mu\, v_\infty}} \qquad (6)$$

wherein: D_u is viscous resistance coefficient, ΔP_1 is Pressure difference of each layer, L is Thickness of each filter layer, v_∞ is Filtration speed, ε is Porosity.

The middle filter layer in the middle of the filter is divided into two layers according to the   porosity. The degree of compression of the upper layer of filter material is small, and the porosity is generally not less than 0.7. This paper is set to 0.7. The lower filter material has a large degree of compression, the porosity is less than the upper layer filter material, the amount of pollution is larger, and the filtering accuracy is higher. Therefore, the porosity of the lower layer is studied as a variable, set as 0.4, 0.5 and 0.6 respectively. The calculation results of each group of data are shown in Table 1.

Table 1. The parameters of fiber filters in each group

Group	Porosity ε	Filter layer thickness L/m	Coefficient of viscous resistance D_u/*10^8	Coefficient of inertia resistance C_2/*10^3
The first upper layer	0.7	0.47	531.91	112.54
The first group lower level	0.4	0.47	584.76	260.52
The second group upper layer	0.7	0.47	531.91	112.54
The second group lower level	0.5	0.47	567.92	186.42
The third group upper layer	0.7	0.47	531.91	112.54
The third group lower level	0.6	0.47	552.33	141.81

4. Numerical simulation results

The pressure drop of fibrous filter is an important judgment factor in determining the filtering performance of the filter medium. For a filter, smaller pressure drop means a reduction in the loss of the filter, the reduction of the operating cost of the equipment, and the protection of the filter medium. At the same time, excessive pressure drop will cause the fluid to be too fast in the filter layer. Excessive flow rate will cause pollutants in the fluid to penetrate the filter layer and affect the water quality. And when the concentration of pollutants that filter water inlet is high, if high-speed filtering is performed, the sewage interception of the filter layer will quickly fill the filter layer gap, the filtration resistance rises rapidly, and the filtration cycle is shortened. This part is analyzed by the pressure and speed cloud diagram and folding line diagram of different porosity and filter layer thickness. The lower porosity and filter layer thickness with better performance is reasonably selective performance.

4.1. Simulation Analysis

Import the drawn grid into the Fluent, the model is selected from the standard k-epsilon model. The filter layer is set to a porous medium. Related boundary condition parameter settings are shown in Table 2.

Table 2. Related parameter settings

category	type	parameter
Fiber filter parameter	Inlet pressure	2MPa
	exit	Free export
	Fluid density	$1.5 \times 10^3 \text{kg/m}^3$
	Fluid viscosity	$1 \times 10^{-3} \text{Pa s.}$
	Porosity of upper filter layer	0.7

The porosity is 0.4   The porosity is 0.5   The porosity is 0.6
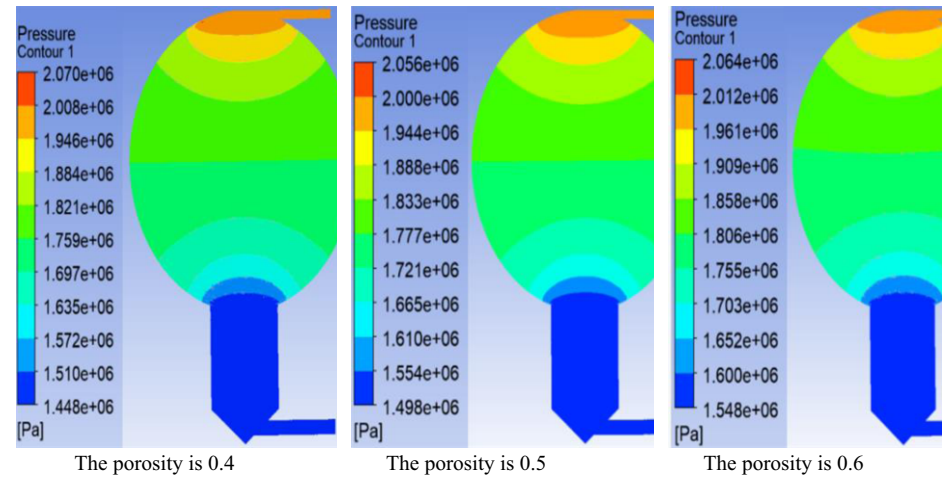
Figure 3. Pressure cloud in fiber filter

The porosity is 0.4   The porosity is 0.5   The porosity is 0.6
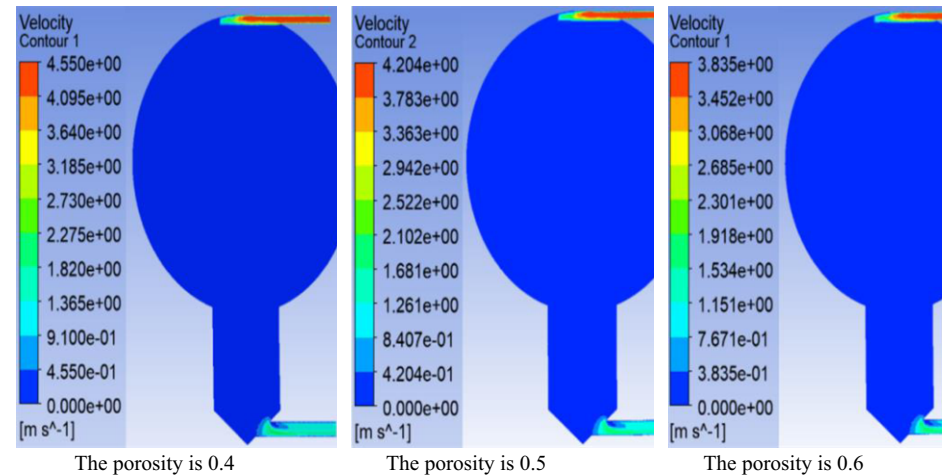
Figure 4 . Velocity cloud in fiber filter

   As can be seen from Figure 3 and Figure 4, no matter how the porosity changes, the trend of the fluid's pressure and speed in the filter is basically the same. It can be seen

from the pressure nephogram that the pressure in the filter decreases gradually. The pressure contour of the upper filter layer is convex downward, larger in the middle and smaller on both sides, while the pressure contour of the lower filter layer is convex upward, smaller in the middle and larger on both sides. The pressure on the lower and exit is basically unchanged due to the small resistance of the fluid. In the speed diagram of the filter, the fluid has not been resistant, the speed is the largest, and the speed of the fluid has decreased sharply after entering the filter layer. After that, the speed of the fluid in the filter layer is basically unchanged. Finally, the flow area at the outlet decreases sharply, resulting in an increase in velocity, but the exit speed is still less than the entry speed due to energy loss in the filter layer.

4.2 The effect of different porosity on the filtration pressure and speed

In order to study the influence of the porosity of the lower half filter layer on the filtration performance, the simulation research is carried out when the porosity of the lower half filter layer is 0.4, 0.5 and 0.6 respectively, and the optimal porosity is determined to obtain the pressure broken line diagram and velocity broken line diagram in the filter, as shown in Figure 5 and Figure 6.
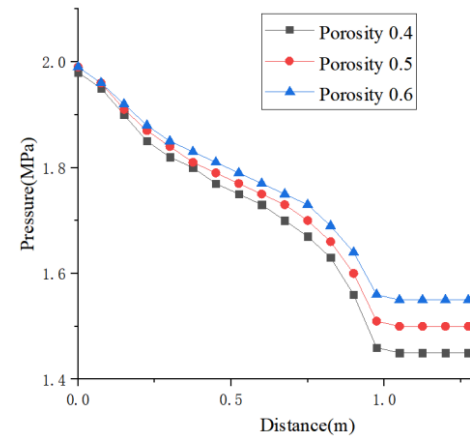
Figure 5 . Pressure curve diagram from inlet to outlet with different porosity
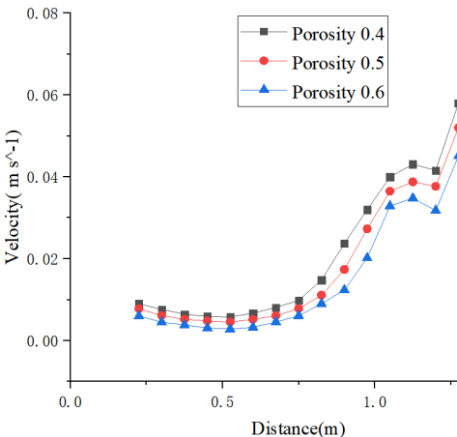
Figure 6 . Velocity curves in different porosity filter layers

It can be seen from Figure 5 that the pressure change law of fluids in the filter is rapidly decreased first, and then stable. The pressure drop increases with the decrease of porosity, and at the same position in the filter, the smaller the porosity, the smaller the pressure. Because the porosity decreases, the water flow resistance becomes larger during filtration, which makes the water head loss larger, and the pressure in the filter layer will decrease rapidly. After the fluid is out of the filter layer (that is, the distance from 1m to 1.5m in Figure 5) is only due to the resistance of the wall surface of the filter, and the wall resistance of the filter is very small, and the fluid pressure is basically unchanged. It can be seen from Figure 6 that the smaller the porosity, the faster the flow rate of the fluid in the filter layer. This is because when the import pressure is unchanged, the smaller the porosity, the smaller the pressure of the filter export, and the larger the difference between the import and export pressure, which accelerates the flow rate of

fluid in the filter. It can be known from the Bernunley equation that the essence of such a change is the result of the static pressure and dynamic pressure in the filter. According to Bernoulli equation, the essence of such change is the result of the continuous transformation of static pressure and dynamic pressure in the filter.

The larger the pressure drop of fluid in the filter, the more energy loss, and the shortage of the filter service life. The flow rate of fluids in the filter is too fast, the filter will have too much pollution, the backwashing frequency will increase, and the filtration cycle will be reduced. In summary, the filter with good performance must have a small pressure drop and filter speed. Therefore, when the porosity of the lower half filter layer is 0.6, the pressure drop and flow rate in the filter are the least, and the comprehensive performance of the filter is the best.

4.3 Effect of filter layer thickness on filtration pressure and speed

In order to further study the effect of the thickness of the filter layer with porosity of 0.6 on the filtration performance, the different percentages of the thickness of the filter layer with porosity of 0.6 in the total thickness were analyzed. Because the porosity of the filter layer is large at the top and small at the bottom, the thickness of the filter layer with porosity of 0.6 does not account for 0 and 100%. At the same time, the proportion of filter layers with different porosity should not be too large or too small, otherwise it will cause uneven filtration. Therefore, this paper simulates when the thickness of filter layer with porosity of 0.6 accounts for 30%, 40%, 50%, 60% and 70%, and obtains the pressure broken line diagram and velocity broken line diagram in the filter, as shown in Figure 7 and Figure 8.
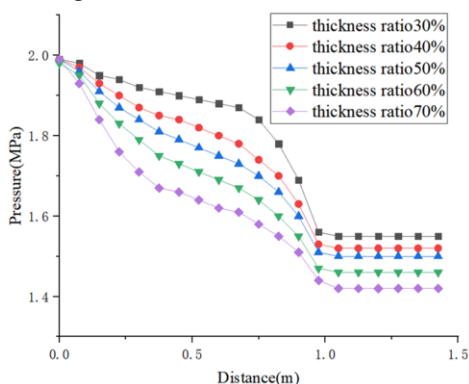
Figure 7 . Pressure curves of different thickness ratios
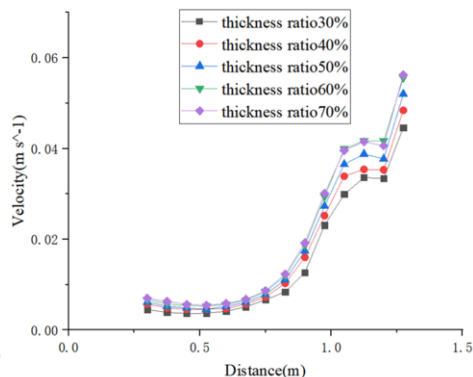
Figure 8. Velocity curves in the filter with different thickness ratios

It can be seen from Figure 7 that no matter how the thickness changes, the pressure drop law of the fluid in the filter is basically the same, which decreases first and then remains unchanged in the transition zone (at the distance of 1m to 1.5m in Figure 7). At the same position in the filter, the greater the proportion of filter layer thickness with porosity of 0.6, the faster the pressure drop speed and the greater the energy consumption. As can be seen from Figure 8, the greater the proportion of filter layer thickness with porosity of 0.6, the faster the flow rate of fluid in the filter layer. The reason for the change of the above two figures is that the head loss of the upper filter layer increases

very little during filtration. The head loss mainly occurs in the lower filter layer. The thicker the thickness of the lower filter layer, the larger the specific surface area provided by the filter material and the better the quality of the effluent water. However, an excessively thick filter layer will increase the head loss in the filtration process. Therefore, the greater the thickness proportion of the filter layer with porosity of 0.6, the more dense the filter layer is, and the greater the flow resistance during filtration, so as to increase the head loss. In addition, increased pressure drop will also accelerate the flow rate of the fluid in the filter layer, which shorten the cycle of the fluid filtration and increase the backwashing frequency. Therefore, excessive losses are caused to fiber balls, reducing the life of fiber balls.

To sum up, the proportion of filter layer thickness has an important impact on the effect of filter. Selecting the filter layer with small thickness proportion can further reduce the pressure difference between the inlet and outlet of the filter and slow down the flow rate of fluid in the filter layer. In this model, when the thickness of filter layer with porosity of 0.6 accounts for 30%, the pressure drop and flow rate in the filter are the smallest, and the comprehensive performance of the filter is the best.

5. Conclusion

(1)In this paper, the physical model was established by SolidWorks, and the pressure nephogram and velocity nephogram of the fluid in the filter were obtained by Fluent. It was found that the pressure of the fluid in the filter decreases first and then remains unchanged, and the velocity decreases first and then increases.

(2)It can be seen from the line chart that the smaller the porosity, the larger the pressure drop of the fluid in the filter, and the faster the flow rate of the fluid in the filter layer. The results show that the porosity of the upper layer of the fiber filter is 0.7, and the porosity of the lower filter layer is 0.6, the fluid import and export pressure difference is minimum. At the same time the energy loss is small, and the fluid has a slower flow rate in the filter. The comprehensive effect of filter is the best.

(3)Further analysis shows that the greater the proportion of the thickness of the lower filter layer, the more the pressure loss of the fluid in the filter and the faster the flow rate. In order to make the filter performance better, the proportion of filter layer thickness with porosity of 0.6 should be 30%.

References

[1]   Miao Z, Zhou N Y, Xie C X. Research Progress of Fiber Filtering Technology in Water Treatment. Contemporary Chemical, 2018;47 (05):1080-1083.
[2]   Wang P. The current status of the research status of domestic coal mine water treatment technology. Same Coal Technology, 2008 (01):1-4.
[3]   Meng X K, Wang T, Sun M M, Cao C Q. The numerical simulation of fluid pressure drop in the porous medium. Journal of Qingdao University of Science and Technology, 2013; 34 (03):254-259.
[4]   Li X H, Zhang Y C, Li H Y, Ding Y M, Yang W M. The fibrous filter optimization simulation of the porous medium model. Film science and technology. 2015; 35 (01):24-27.
[5]   Yang M L, Zhou Y, Yang X W, Zhou W P, Qiang R, Wang J L, Zhu K. Optimized design based on Solidworks supporting support design. Petrochemical equipment, 2021; 50 (04):43-47.
[6]   Gao L Z, System design and fiber filter simulation research of mine water purification station. Taiyuan University of technology, 2017.
[7]   Wang R J, Fluent technical foundation and application example. Tsinghua University Press, 2007.

[8]   He X W, theory and practice of mine water treatment and resourceization. Coal Industry Press, 2009.

[9]   Li B, Ansys Workbench design, simulation and optimization. Tsinghua University Press, 2011.

[10] Wang L, Shi J F, Guo W Z, Zhao X Y, Ren W J. Research on CFD -based mineral spin nozzle structure simulation. Coal Technology, 2021; 40 (8): 193-195.

[11] Nariyan E, Sillanp M, Wolkersdorfer C. Electrocoagulation treatment of mine water from the deepest working European metal mine – Performance, isotherm and kinetic studies. Separation and Purification Technology. 2017; 177: 363-373.

[12] Pinto P X, Al-Abed S R, Balz D A, Butler B A, et al. Bench-Scale and Pilot-Scale Treatment Technologies for the Removal of Total Dissolved Solids from Coal Mine Water: A Review. Mine Water and the Environment. 2016; 35: 94–112.

[13] Thiruvenkatachari R, Francis M, Cunnington M, Su S. Application of Integrated Forward and Reverse Osmosis for Coal Mine Wastewater Desalination. Separation and Purification Technology. 2016; 163: 181-188.

Deep Learning Based Thermal Stress and Deformation Analysis of Satellites

Zeyu CAO[a,b], Wei PENG[a], Xiaoya ZHANG[a] and Wen YAO[a,1]

[a] *Defense Innovation Institute, Chinese Academy of Military Science, Beijing 100071, China*
[b] *The No.92941st Troop of PLA, Huludao 125001, China*

Abstract. When analyzing the thermal stress and deformation of satellites in orbit, the traditional numerical methods, such as the finite difference and the finite element, are expensive and time-consuming. To improve computational efficiency, we propose a deep-learning based surrogate to immediately predict the thermal stress and deformation of a satellite with a given temperature field, where the U-Net is employed to learn the end-to-end mapping from the temperature field to the thermal stress and deformation. A data set with less smooth temperature fields is generated to augment the training data, by which the accuracy and generalization performance of the model is significantly improved. Combined with a rapid temperature prediction method, the model predicts the thermal stress and deformation of a satellite motherboard given several heat sources, verifying the feasibility and effectiveness of the proposed method.

Keywords: Deep Learning, thermal stress and deformation, satellites motherboard

1. Introduction

As influential performers of space missions, satellites play an irreplaceable role in communication, remote sensing, navigation, and military reconnaissance [1]. Nevertheless, their reliability and longevity are long-stand challenges. The satellite components will be periodically exposed to alternating high and low temperature fields from outer space during the period of on-orbit. The change of temperature will cause fatigue, delamination, and fracture of satellite components, affecting their operational performance and service life [2]. Besides, the satellite components will inevitably generate immense heat during operation due to high power density, which will lead to a series of problems such as thermal deformation, thermal buckling or thermal vibration [3]. All above will significantly affect the pointing precision of the satellite when performing missions. Therefore, it is essential to analyze the thermal stresses and deformation of the satellite.

At present, there are three primary means to analyze the in-orbit satellites: experimental, simulation and theoretical [4]. For experimental methods, the ground-based simulation test is expensive, and it still cannot measure the parameters directly in a thermal vacuum tank accurately; besides, the increasing size of the satellite structure makes it more challenging to perform ground tests of a full-size model of the satellite.

Therefore, theoretical analysis and simulation have become the mainstream methods for the in-orbit analysis of satellites [5]. However, these traditional numerical calculation methods, such as finite difference and finite element, often cost much calculation time [6]. It is difficult to provide an immediate response to the thermal stresses and deformation when the temperature field changes. Therefore, it is necessary to develop an efficient surrogate model with high precision that meets the fast calculation requirement.

With the booming development of artificial intelligence, deep learning technology based on Deep Neural Network (DNN) has emerged in many fields, such as computer vision and natural language processing [7]. Due to the universal approximation ability and efficient computation of neural networks [8], the surrogate modeling technique based on deep learning provides a paradigm to construct high-precision models for thermal stress and thermoelastic deformation.

In recent years, many deep learning based surrogate models for regression between high-dimensional variables have emerged in various fields. In thermodynamics, Rishi Sharma et al. [9] solved thermal transport problems by U-Net structure. In aerodynamics, Shen et al. [10] developed a generative deep learning model to generate the numerical solutions for N-S equations. Also, Thuerey et al. [11] investigated the accuracy of deep learning models for the inference of Reynolds-Averaged Navier-Stokes solutions. In addition, Cheng et al. [12] predicted the 2D velocity and pressure fields around arbitrary shapes in laminar flows by deep learning based surrogate model. In optics, Li et al. [13] proposed a deep learning framework for real-time predictions of the scattering from an isolated nano-structure in the neared regime. The literature above has demonstrated the powerful regression capabilities of surrogate models endowed with deep learning techniques.

In the field of elasticity, Saurabh Deshpande et al. [14] predicted the response of super elastomers under load by the U-Net framework. The proposed approach to similar problem motivated us. In this paper, we introduce a deep learning based method to predict thermal stress and deformation of the satellite. We simply the problem as predicting the thermal stress and thermal deformation of a satellite motherboard where some heat sources distribute in. Firstly, to address the point of the problem, we implement the regression task, which maps the temperature field to thermal stress and deformation by U-Net structure. Secondly, to augment the training data, a data set with low smoothness is used for training. In this way, the accuracy and generalization performance of the model is well improved. Experiments show that the U-Net surrogate can effectively return accurate estimates of the thermal stress and deformation. Finally, the surrogate is used to predict the thermal stress and deformation of the satellite motherboard. This new approach can be used in real-time monitoring techniques. Also, it helps to promote the application of deep learning in practical engineering and enrich the solution to engineering problems.

This paper is organized as follows. In section 1, we introduce the background and related works. Section 2 presents the essential mathematical models of the thermal field, thermal stress, and deformation. Section 3 describes the training processes of the planar thermoelastic problem by U-Net. Then section 4 shows the experiment results. In Section 5, the summary of the research is outlined.

2. Mathematical model of thermodynamic coupling problems

This section investigates linear thermoelastic problems driven by thermal properties. The solution of thermodynamic coupling problems is segmented into two processes, heat conduction problem and thermoelastic problem. We discuss the two mathematical models respectively.

2.1. Mathematical model for heat conduction problem

This paper studies the thermal stress and deformation of a satellite motherboard where some heat sources distribute in. Firstly, we need to calculate the temperature field of the motherboard. The thermal layout model of the satellite motherboard was previously defined by Chen et al. [15], which is illustrated in Fig.1. The thermal layout shows a two-dimensional satellite motherboard with partial openings, with three sides of the plate adiabatic and one side with a convective heat transfer coefficient of . FDM method is used to build the dataset, the process of which is indicated by the red arrow. The blue arrow indicates the surrogate model approach. In this way, we can focus our energy on the tricky part.

The steady-state temperature field T , which contains multiple heat sources in the two-dimensional motherboard, can be calculated by the Poisson equation. The partial differential equations are as follows,

$$\frac{\partial}{\partial x}\left(k \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y}\left(k \frac{\partial T}{\partial y} \right) + \phi(x, y) = 0,$$

$$\text{Boundary}: T = T_0 \text{ or } k \frac{\partial T}{\partial \mathbf{n}} = 0 \text{ or } k \frac{\partial T}{\partial \mathbf{n}} = h\left(T - T_0 \right), \tag{1}$$

where k means the thermal conductivity of the layout domain, $\phi(x, y)$ represents the power distribution of heat sources and h means the convective heat transfer coefficient. The following Poisson equation includes three different boundary conditions: Dirichlet (isothermal), Neumann (adiabatic), or Robin (convective). The power distribution function $\phi(x, y)$ is determined by the positions and power of different heat sources, which can be expressed as

$$\phi(x, y) = \begin{cases} \phi_i, (x, y) \in \Gamma_i, \\ 0, (x, y) \notin \cup\{\Gamma_i\}, \end{cases} \tag{2}$$

where ϕ_i means the intensity of one single heat source and Γ_i denotes the area the heat source covered. When the layout and the power of heat sources changes, functions change, so as to influence the steady-state temperature field of the domain.
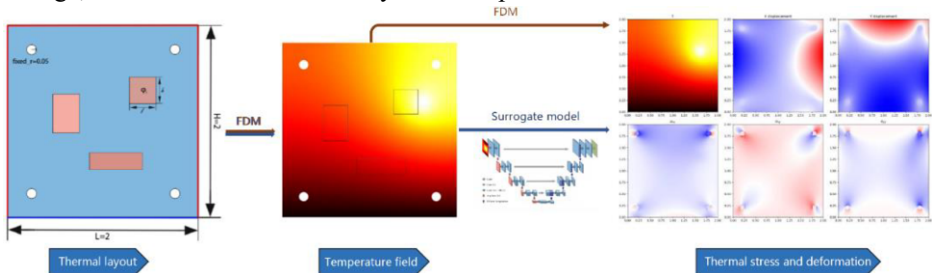
Figure 1. Model definition and calculation process.

2.2. Mathematical model of thermoelastic problem

In this part, the temperature field is given as an input. It can be obtained as a solution to the steady-state thermal equation (Poisson equation). The linear elasticity coefficient α is assumed to not change with temperature.

As the elastomer is subject to external constraints as well as mutual constraints between parts of the body, when the temperature changes, The motherboard tends to expand, and the constraints on elastomers will cause thermal stress. It would in turn generate new additional strains due to elasticity. The strain components and temperature T satisfy

$$
\begin{cases}
\sigma_x = \dfrac{E}{1-\mu^2}\left(\dfrac{\partial u_x}{\partial x} + \mu \dfrac{\partial u_y}{\partial y}\right) - \dfrac{E\alpha T}{1-\mu}, \\[2mm]
\sigma_y = \dfrac{E}{1-\mu^2}\left(\dfrac{\partial u_y}{\partial y} + \mu \dfrac{\partial u_x}{\partial x}\right) - \dfrac{E\alpha T}{1-\mu}, \\[2mm]
\sigma_{xy} = \dfrac{E}{2(1+\mu)}\left(\dfrac{\partial u_y}{\partial x} + \dfrac{\partial u_x}{\partial y}\right).
\end{cases}
\tag{3}
$$

According to the equilibrium differential equation, the thermal displacement components satisfy

$$
\begin{cases}
\dfrac{\partial^2 u_x}{\partial x^2} + \dfrac{1-\mu}{2}\dfrac{\partial^2 u_x}{\partial y^2} + \dfrac{1+\mu}{2}\dfrac{\partial^2 u_y}{\partial x \partial y} - (1+\mu)\alpha \dfrac{\partial T}{\partial x} = 0, \\[2mm]
\dfrac{\partial^2 u_y}{\partial y^2} + \dfrac{1-\mu}{2}\dfrac{\partial^2 u_y}{\partial x^2} + \dfrac{1+\mu}{2}\dfrac{\partial^2 u_x}{\partial x \partial y} - (1+\mu)\alpha \dfrac{\partial T}{\partial y} = 0.
\end{cases}
\tag{4}
$$

The stress boundary conditions according to displacement are

$$
\begin{cases}
l\left(\dfrac{\partial u_x}{\partial x} + \mu \dfrac{\partial u_y}{\partial y}\right)_s + m\dfrac{1-\mu}{2}\left(\dfrac{\partial u_x}{\partial y} + \dfrac{\partial u_y}{\partial x}\right)_s = l(1+\mu)\alpha (T)_s, \\[2mm]
m\left(\dfrac{\partial u_y}{\partial y} + \mu \dfrac{\partial u_x}{\partial x}\right)_s + l\dfrac{1-\mu}{2}\left(\dfrac{\partial u_y}{\partial x} + \dfrac{\partial u_x}{\partial y}\right)_s = m(1+\mu)\alpha (T)_s.
\end{cases}
\tag{5}
$$

According to the equations above, the thermal stress and deformation of the satellite motherboard with any heat source layout can be calculated.

3. Surrogate model of thermal stress and deformation based on U-Net structure

This section describes the surrogate model of thermal stress and deformation based on U-Net, which can predict the planar thermoelastic problem when given the temperature field. According to the above mathematical models, the key lies in solving the equations of thermoelastic dynamics. Therefore, we focus on mapping the temperature field to thermal stress and deformation. It is organized as follows. Section 3.1 introduces the U-Net architecture. In Section 3.2, the construction of the data set is described in detail. Section 3.3 presents the training process.

3.1. U-Net architecture

The structure of U-Net is shown in Fig.2. It is a symmetric structure similar to a U-shape, consisting of two main parts, encoder and decoder. The encoder is the feature extraction part, and it is a classical VGG-16 network similar to the coding process, which learns multi-scale features of an image through pooling and convolution operations; The decoder is an up sampling process, which reduces the image size layer by layer through deconvolution operations. U-Net fuses the feature extraction part with same scale, then obtains more features from the lower-level feature maps, effectively preserving the information in the original image and preventing the loss of too much detailed information. In this way, U-Net combines features at different scales and increases the amount of information, and the accuracy of model benefits from this structure. Referring to the above characteristic, the U-Net is well suited for regression tasks between images.
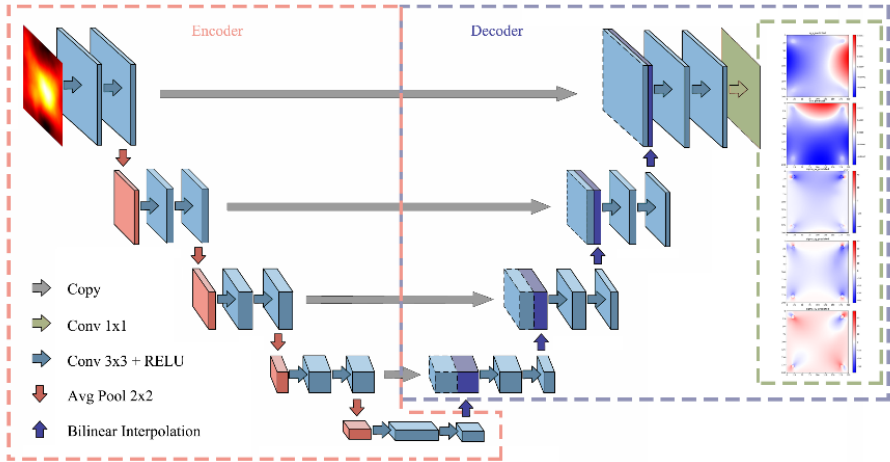
Figure 2. U-Net architecture.

3.2. Data preparation

The specific task problem is shown in Fig.1. We consider a two-dimensional rectangular satellite motherboard with size $L \times H$. The motherboard is not subjected to self-weight loads. It has four circular holes inside, which simulate the screw articulation of an actual engineering component. There is no displacement at the edges of the circular holes. Thermo-elastic properties are assumed to be isotropic and linear. In this model, parameters are the same as those of aluminium and will be considered around a reference temperature $T_0 = 293K$. Stress and flux-free boundary conditions are applied on the outer boundary of the plate. Detailed parameters are shown in Tab.1.

In the U-Net, the input is a two-dimensional planar temperature field in the form of matrix. The outputs are the corresponding thermal stress matrix and the thermal deformation matrix. The Finite-Difference Method (FDM) [16] was used for the calculation. The computational domain is a 200×200 uniform grid, and the 200×200 temperature field matrix is the input; five 200×200 matrices are outputs, which

represent x-direction displacement(u_x), y-direction displacement(u_y), x-direction thermal stress(σ_{xx}), y-direction thermal stress(σ_{yy}), tangential stress(σ_{xy}) respectively.

Table 1. Parameter list

Option	Symbol	Value	Units
Length of plate	L	20	cm
Height of plate	H	20	cm
Radius of the holes	R	0.5	cm
Thermo-conductivity	k	0.5	$W/(m \times k)$
Linear coefficient expansion	α	$1e-5$	$1/{}^\circ C$
Young's modulus	E	$50e3$	MP
Poisson's ratio	μ	0.2	/

Referring to the solution of Poisson equation, the temperature field of satellite motherboard is very smooth. To augment the training data, two data sets with lower smoothness than actual conditions are used for training. The temperature field is generated by the gaussian random field. When we adjust the standard deviation and mean of the gauss function, the smoothness of temperature changes as well. We generated two training sets, respectively DS and DC (as shown in Fig.3). The DS and DC are two samples in the sample set with a sample size of 10000. DS means relatively smooth temperature and DC means relatively coarse one. However, both of them are more complex than the temperature field of the satellite motherboard.Also, we have 500 general samples as test set TS, and the smoothness level of it is the same as DS. The TS is generated in the same way of training set.

DS   DC
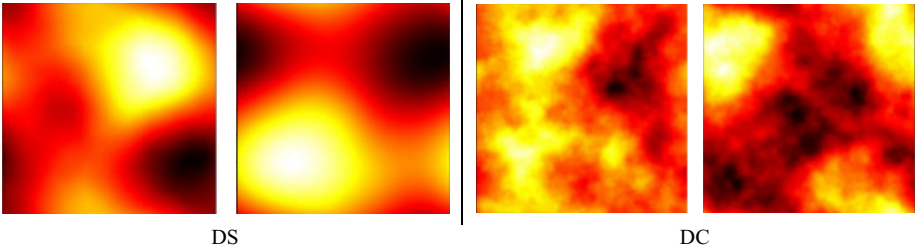
Figure 3. Training set comparison.

3.3. Data preparation

Given an arbitrary temperature field T , we can obtain the outputs from the neural network surrogate model, i.e., the predicted thermal stress and deformation. The training objective of the U-Net model is to minimize the difference between the predicted outcome $\hat{Y}$ and the label Y , so that the surrogate model can fit the labels. Once the model is trained, it can be applied in inference to the thermal stress and deformation corresponding to any temperature field. This task has five predicting targets, and if they were trained individually in a single-channel manner, it would be time-consuming. To solve this problem, this paper adopts multi-task training method.

In this regression task between images, the loss function is defined by

$$Loss_i = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2. \tag{6}$$

The dimensions between different tasks are different. To ensure the balance of training accuracy as well as training speed between different tasks, the normalized operation is applied, and the loss function is weighted according to the task characteristics just as

$$Loss = \sum_{i=1}^{m} w_i \times Loss_i, \tag{7}$$

where m means the number of tasks, and w_i is the weighted value determined by loss of different tasks. In this way, we map the thermal field to thermal stress and deformation.

4. Experiment results

In this section, the experiment results are discussed. AdamDelda [17] is chosen as the optimization. The U-Net model is implemented by PyTorch 1.8. For training, we set the epoch to 500 and the batch size to 64.

4.1. Performance of U-Net

The predictions of the surrogate model after 500 epochs are shown in Fig.4. It shows the label of a randomly chosen temperature field in TS, along with the output of the trained neural network and the absolute error.

The mean relative error(MRE) in the pixel-by-pixel output is only 2.13%. Average per-pixel error is computed relative to "ground truth", which is determined by running finite difference to very high precision. Through such a deep learning surrogate model, the computation time is reduced from 2min to 0.23s, effectively saving cost of time. This demonstrates the feasibility of using the U-Net model for regression between ultra-high dimensional variables. It also illustrates the effectiveness of the deep learning based surrogate model of thermal stress and deformation.
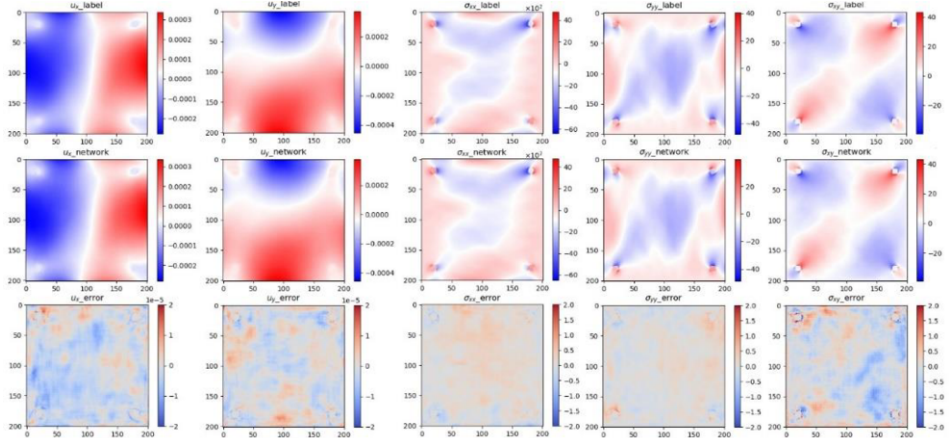
Figure 4. Comparison between ground truth and network result(TS).

4.2. The performance of data augmentation on the generalization of prediction results

We compared the performance of the surrogate on different training sets after 240 epochs. U-Net was trained on DS and DC respectively (Fig.3), then they were both tested on the TS.

The results are shown in Tab.2. It can be seen that the surrogate models trained on both data sets exhibit good performance. However, the MRE of DC is obviously less than that of DS, even though DS is as smooth as TS. It can be explained as data augmentation. The more complex data set (DC) increase the diversity of the data set, which improves the accuracy and generalization of the surrogate model.

Table 2. Performances on the TS for different data sets

Option	MRE/%	
	DS	DC
u_x	3.32	2.61
u_y	3.47	2.37
σ_{xx}	3.92	2.16
σ_{xy}	3.92	2.32
σ_{yy}	3.22	2.19

4.3. Application: Thermal stress and deformation analysis of the satellite motherboard

When given the heat source layout of a satellite motherboard, the temperature field of it is calculated by finite difference. Then the surrogate, which maps temperature to thermal stress and deformation, is applied. Fig.1 shows a randomly generated heat source layout and the corresponding temperature field of the satellite motherboard. Fig.5 shows the corresponding thermal stress and deformation calculated entirely by the finite differences(label), the output of the trained neural network and its absolute error. The MRE in the pixel-by-pixel output is only 1.76%. It is less than that on TS. This phenomenon also benefits from the data augmentation by DC. This demonstrates that the deep learning-based surrogate model is effective in solving complex thermodynamic coupling problems such as satellite thermal stress and deformation.
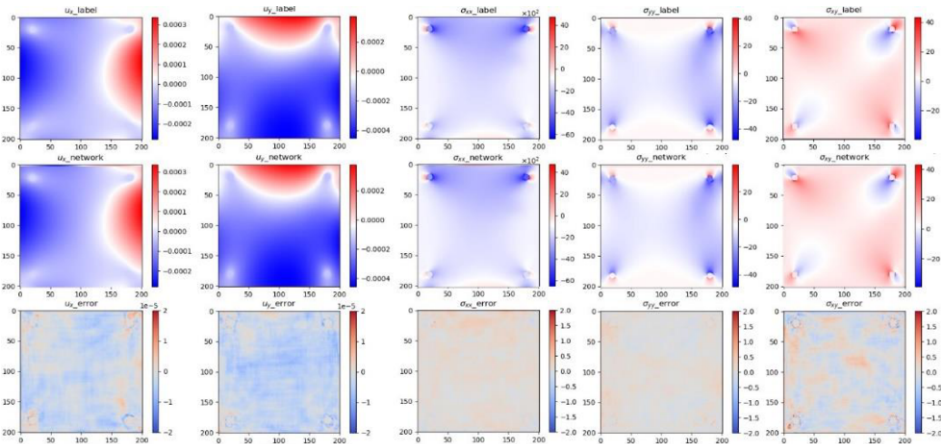
Figure 5. Comparison between ground truth and network result(Satellite motherboard).

5. Conclusions

This paper presents an end-to-end deep learning based surrogate modeling method for predicting the thermal stress and deformation of satellites. The neural network is used to construct surrogate models for fast simulating complex thermodynamic coupling problems, where traditional numerical methods often cost much calculation time and resources.

The prediction problem is simplified as predicting the thermal stress and thermal deformation of a satellite motherboard where some heat sources distributed in. We build a surrogate model which maps the temperature field to the thermal stress and deformation, and then make some data augment strategies to improve the accuracy and generalization performance of the model. The surrogate model later is used to predict the thermal stress and deformation of the satellite motherboard with some heat sources. This case verifies the feasibility and effectiveness of our deep learning surrogate model.

The results demonstrate that this deep learning-based surrogate model method is effective in solving complex thermodynamic coupling problems such as thermal stress and deformation of satellites.

Acknowledgments

References

[1] Wu, K.L. 1999 Transaction and transition: An Asian student's encounter with American texts in an Introduction to Literature classroom (The University of Iowa).

[2] Soutis C. Fibre reinforced composites in aircraft construction. 2005 Progress in aerospace sciences 41 143–151.

[3] Thornton E A and Kim Y A. Thermally induced bending vibrations of a flexible rolled-up solar array. 1993 Journal of Spacecraft and Rockets 30 438–448.

[4] Farrahi A and P´erez-Grande I. Simplified analysis of the thermal behavior of a spinning satellite flying over sun-synchronous orbits. 2017 Applied Thermal Engineering 125 1146–1156.

[5] Liu G P and Zhang S. A survey on formation control of small satellites. 2018 Proceedings of the IEEE 106 440–457.

[6] Bao K, Yao W, Zhang X, Peng W and Li Y. A physics and data co-driven surrogate modeling approach for temperature field prediction on irregular geometric domain. 2022 arXiv preprint arXiv:2203081502022.

[7] Liu W, Wang Z, Liu X, Zeng N, Liu Y and Alsaadi F E. A survey of deep neural network architectures and their applications. 2017 Neurocomputing 234 11–26.

[8] Zhao X, Gong Z, Zhang J, Yao W and Chen X. A surrogate model with data augmentation and deep transfer learning for temperature field prediction of heat source layout. 2021 Structural and Multidisciplinary Optimization 64 2287–2306.

[9] Sharma R, Farimani A B, Gomes J, Eastman P and Pande V. Weakly-supervised deep learning of heat transport via physics informed loss. 2018 arXiv preprint arXiv:1807.11374.

[10] Wang S, Nikfar M, Agar J C and Liu Y. Stacked generative machine learning models for fast approximations of steady-state Navier-stokes equations. 2021 arXiv preprint arXiv:2112.06419.

[11] Thuerey N, Weißenow K, Prantl L and Hu X. Deep learning methods for Reynolds-averaged Navier–stokes simulations of airfoil flows. 2020 AIAA Journal 58 25–36.

[12] Chen J, Viquerat J and Hachem E. FEM-based real-time simulations of large deformations with probabilistic deep learning. 2019 arXiv preprint arXiv:1910.13532.

[13] Li Y, Wang Y, Qi S, Ren Q, Kang L, Campbell S D, Werner P L and Werner D H. Predicting scattering from complex nano-structures via deep learning. 2020 IEEE Access 8 139983–139993.

[14] Deshpande S, Lengiewicz J and Bordas S. FEM-based real-time simulations of large deformations with probabilistic deep learning. 2021 arXiv preprint arXiv:2111.01867.

[15] Chen X, Yao W, Zhao Y, Chen X and Zheng X. A practical satellite layout optimization design approach based on enhanced finite-circle method. 2018 Structural and Multidisciplinary Optimization 58 2635–2653.

[16] Reimer A S and Cheviakov A.F. A matlab-based finite-difference solver for the Poisson problem with mixed Dirichlet–Neumann boundary conditions. 2013 Computer Physics Communications 184 783–798.

[17] Zeiler M D. Adadelta: an adaptive learning rate method. 2012 arXiv preprint arXiv:1212.5701.

Construction Strategy of Informatization of Rural Ethnic Cultural Archives Based on Big Data

Qi YANG, Shilong WANG and Jinghuan ZHU[1]
Guangxi Science & Technology Normal University, Laibin, China

Abstract. Rural ethnic cultural archives have great potential in serving rural revitalization. Big data technology improves the application ability of big data by improving "processing ability", and constructs a "big data + archives management" mechanism, which can give more convenient play to the value of archives. Starting from the problems existing in the construction of archives informatization talents and archives digitization technology system, this paper puts forward the information construction strategies of rural ethnic culture archives, such as accelerating the transformation and upgrading of rural ethnic cultural archives management, innovating the effective path of the development and utilization of rural ethnic cultural archives resources and so on.

1. Introduction

Rural ethnic archives are very important national cultural resources and an integral part of building the common spiritual home of the Chinese nation. Most ethnic minority areas in the country are located in remote areas with special geographical environment. In the long-term historical development process, they have formed distinctive national culture and accumulated precious archives of national cultural heritage. As the historical evidence, the archives of ethnic minority areas provide a large number of historical materials for the inheritance of Chinese civilization, which is conducive to carrying forward and developing the excellent traditional culture of all ethnic groups in China [1]. Big data is a collection of data, including a series of professional technologies for data value obtain, such as collection, storage, management, analysis and security. Big data technology is to enhance the application ability of big data by improving "processing ability" [2]. The characteristics of big data technology, such as large capacity, fast response speed and many categories, have been widely used in all walks of life. Under the background of rural vitalization and big data, relying on information technology to mine and use rural ethnic cultural archives has become a trend [3]. Archivists should think about how to apply information and electronic technology and computer network system in the management and utilization of rural

---

[1] Corresponding author: Jinghuan ZHU, Guangxi Science & Technology Normal University, Laibin, China; Email: zhujinghuan@gxstnu.edu.cn

ethnic cultural archives to realize the information construction of archives resources, and build a "big data + rural archives management" mode on the basis of saving human and material resources, so as to give better play to the value of rural ethnic cultural archives [4].

2. Purpose of informatization construction of rural ethnic cultural archives

With the development of information science and technology, the object of archives management presents the trend of large-scale and complexity. By combining big data technology with archives management, we can give full play to the advantages of high efficiency and convenience of big data technology, as well as the functions of fast processing and large storage. Archives managers can complete efficient and high-quality management only by daily operation and maintenance of computer system. Integrating big data technology into archives management greatly reduces the labor and time cost of management. Comprehensively promoting rural vitalization is the only way to implement the grand goal of China's socialist modernization and the inevitable requirement of the development of the new era. The traditional archives management mode and thinking can not meet the needs of contemporary development, which limits the improvement of the efficiency and quality of archives management. With the rapid development and revitalization of various rural undertakings, the level of rural economic and social development has also moved to a new level, and the rural archives have also increased significantly, which requires the rural cultural archives management to keep pace with the times and comply with the development of the times [5]. Archives management and research work should keep up with the pace of rural economic and social development, integrate big data technology and fully implement modern and intelligent management, so as to provide convenient, fast, accurate, timely and effective archives utilization services for rural revitalization, create greater social value and integrate into the era wave of rural vitalization [6].

3. Problems in the informatization construction of rural ethnic cultural archives

3.1. Problems in the construction of archives digitization technology system

At present, the digital collection of rural ethnic cultural archives is completed by typing and inputting with computer system and digital scanning with electronic scanner. Typing is not only slow, but also time-consuming and labor-consuming. Scanning by electronic scanner is easily affected by resolution and device memory. The digital technology of rural ethnic cultural archives focuses on the development of text input system, and ignores the research and development of multimedia information technology such as image and sound. The digitization of rural ethnic cultural archives presents the characteristics of "surface", which still stays in the input of catalogue, digital scanning of archives and so on. This way is not conducive to the retrieval and reading of archival researchers, nor to the development and utilization of the cultural value of rural archives [7]. Only relying on text input system and scanning technology can not fully show the rich connotation and precious value of rural ethnic cultural archives. In order to make archives work better serve the revitalization and

development of rural areas, the country needs rich, efficient and convenient digital technology as support, so as to realize the digitization of rural ethnic cultural archives [8]. The digitization of rural ethnic cultural archives includes the correct selection of parameters such as scanning technology, graphic editing, image format and storage, as well as the adoption of information technology, including scanning processing, decontamination treatment, quality inspection, and the association of digitized images, documents and literature indexing information [9]. The digitalization of archives is not yet mature, and the theoretical research on the digitalization of archives is still in its infancy. At present, the research focus is not obvious, and stays in the conceptual exploration and research stage, mainly focusing on the digital construction of some special archives and the establishment of digital archives, and there is a lack of theoretical research with guiding significance for practical work.

3.2. Problems in the construction of archives informatization talents

The informatization consciousness and ability of rural national culture archives staff can not meet the needs of archives digital development. Most of the human resources for the digital construction of rural ethnic cultural archives come from the archives administration department. They have received professional training in the digital construction of archives. However, due to the lack of standardized and systematic skill training and professional education, they lack professional knowledge in computer, big data technology and other aspects [6]. At present, some of the personnel engaged in the digitization of rural cultural archives are technical talents who have received professional education in information technology and master professional knowledge of archives at the same time; There are also college graduates majoring in archives, and archives professionals who master big data technology by themselves. The limitation of the current talent structure is that talents with professional knowledge and skills of rural cultural archives can not master the knowledge of information technology and carry out the in-depth digital construction of rural cultural archives. Talents with information technology professional background do not master the professional knowledge of archives, so it is difficult to really understand archives work and integrate with their own information technology. There is a lack of personnel with information technology professional background in rural cultural archives management. Under the background of big data, archives personnel should not only have the ability and knowledge of archives information collection, sorting, transmission and identification, but also master big data processing, multimedia, network communication technology and other technologies. In the digital construction planning, function design, system analysis and technical realization of rural ethnic cultural archives, there are few talents with dual abilities of information technology and archives who play a leading and communication role. Especially in the archives institutions in ethnic areas, even if ethnic cultural archives are collected here, due to its remote location and underdeveloped economy, there is a greater lack of high-quality information technology and archives professionals. Due to the limitations of geographical and economic conditions in rural areas, archives institutions have no talent competitiveness, so it is difficult to introduce and retain high-level talents, and even the original talents flow to large cities with high treatment, flexible management and large development space. Only by formulating attractive talent incentive mechanism and management policies can we solve the problem of lack of national archives management talents [10].

4. Accelerate the transformation and upgrading of rural ethnic cultural archives management in combination with Rural Revitalization

Popularizing the awareness of rural archives is the ideological basis and premise for comprehensively improving the level of rural ethnic cultural archives management. Therefore, we should not only take effective forms and means to widely publicize the archives work, such as actively publicizing and implementing the archives law, but also seize various opportunities, especially in combination with rural reality, strengthen the specialization, standardization, digitization, networking and Comprehensively popularize the knowledge of informatization and other construction, implement the goal of archives management in the new era, and build the rural culture with archives resources as the carrier into the concept of archives work that is interlinked and integrated with the rural development in the new era [11]. First, actively promote the investigation and general survey of rural archival resources, establish a more scientific collection and management system of rural archival cultural resources in combination with the actual construction of various industries such as rural vitalization and rural environmental improvement, and fully integrate rural culture. As shown in Figure 1, especially all kinds of archival cultural information resources related to rural vitalization (including material, non-material and characteristic archives) into the scope of scientific management, so that the archival cultural resources generated and accumulated in the process of rural development can be scientifically and effectively managed and protected [12]. Second, in the construction of rural archives resources, we should pay attention to optimizing the content structure of rural national culture archives resources, and take corresponding scientific methods to manage and utilize archives of different categories, forms and carriers. From the perspective of serving rural revitalization, the competent department of rural archives should give full play to the advantages of administrative means and professional foundation, coordinate and jointly tackle key problems, implement the main body of responsibility for the management of rural ethnic cultural archives, and create a social atmosphere for the standardized construction of rural archives. Third, talent modernization is the premise of the modernization of rural ethnic cultural archives, and the talent team is the main body of rural archives to serve rural revitalization. It is necessary to strengthen the selection, employment and training of archives information management talents represented by big data technology, build a rural archives work team proficient in archives specialty, mastering modern information technology and making progress in harmony with rural revitalization, and provide talent guarantee and intellectual support for the "living" of rural ethnic cultural archives [13]. Fourth, with the help of the national strategy of rural revitalization, we should speed up the investment of modern archives management equipment and facilities, introduce modern archives management technology, promote the renewal and application of modern archives management equipment and technology, promote the transformation of rural archives management to modernization and informatization, promote the digitization, networking and informatization of rural archives as a whole, and enrich rural ethnic cultural archives resources, Make rural ethnic cultural archives "fire up" and contribute to rural vitalization and rural social development [14].
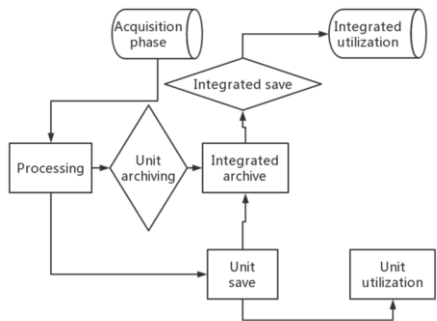
Figure 1 Process model of integrated management of rural ethnic cultural archives resources

5. Conclusions

The development of archival information resources is to sort out the disordered archival information according to the law of information development and scientific methods, so as to make it orderly and systematic. Through the excavation of the external characteristics and cultural connotation of archives, a variety of retrieval methods are provided for the full development and utilization of archives information resources. The way of information organization has developed from manual classification, indexing and sorting to the development of network information resources (text, hypertext and multimedia information). We can choose the organization mode according to the characteristics of organization information. Full text retrieval is not only a processing method of text information, but also the simplest organization method. It only needs to input the full-text file information into the system as the basis of retrieval, and the application range of database mode is very wide. The database standardizes a large number of documents and archives data and saves them in the database in a fixed format for quick search. Hypertext organization is actually an extension of database organization and an innovation of database organization. The main reason is that its storage mode is not linear, but network storage according to internal relations. Because it conforms to people's thinking habits, it is also used more. There are also many, such as the organization of theme trees and search engines. Because the diversity of carriers of rural ethnic cultural archives resources (shell leaves, metals, stones, silk, etc.) and the diversity of information forms (audio, video, images, etc.),so these form the multimedia organization mode of rural ethnic cultural archives resources.

   The object-oriented data model objectively describes the problems between file entities. Each object corresponds to a file entity, and each object has a specific identifier and value. This object is not limited to data, but can also be text, chart, picture, audio, video, etc. In object-oriented organization, objects and their constraints are regarded as a class. Under a large category, it can be divided into many subclasses. The constraint of a subclass can be to integrate the original class or reset its operation mode. Generally, relational database considers the overall structure, how to extract the information of keywords, topics, titles and other fields, how to store them in the database, how to establish an index to provide retrieval, and object-oriented database considers the establishment of data model. The establishment of object-oriented data

model is only the production of the collection, compilation, research and retrieval of ethnic archives information. In the face of a large number of rural ethnic cultural archives resources, we should also use the way of data mining to organize the archives information under the condition of simple digital operation, so as to make the archives compilation and research materials more rich, detailed and closely linked.

Acknowledgments

References

[1] Mi juanting, Wan Zhongna. On the role of minority archives in the development of Minority Areas -- Taking Gansu Province as an example [J]. Archives, 2017 (5): 52-55.

[2] Li Jue. Improvement strategy of archives management business of petroleum enterprises under the background of big data [J]. Office business, 2022 (1): 118-119.

[3] Dong Fei. Path analysis of innovative enterprise archives management under the background of big data era [J]. Urban construction archives, 2021 (12): 101-102.

[4] Li Xiaomei. Measures for informatization construction of career archives under the background of Internet [J]. Heilongjiang archives, 2021 (6): 260-261.

[5] Zhang Tenghua. Thoughts on establishing archives resource management system suitable for rural development [J]. Heilongjiang archives, 2022 (1): 108-110.

[6] Zhang Tenghua. Comprehensively improve the level of rural archives management in rural vitalization -- an analysis of the path of rural archives management in the new era [J]. Heilongjiang archives, 2021 (6): 244-245.

[7] Zhang Donghua, Gao Rui. On the path of constructing the cultural field of public archives under the background of digital village strategy [J]. Archives and construction, 2020 (10): 36-40,44.

[8] Zhou Linxing, Cui Yunping. Development of rural archives memory resources for Digital Humanities: value, mechanism and path choice [J]. Beijing archives, 2021 (10): 10-14.

[9] Zhao Demi. Research on the digital construction of historical archives of ethnic minorities in Yunnan [D]. Yunnan University, 2011,50-64.

[10] LV Faxiang. Focus on grass-roots governance, Serve rural vitalization and promote the overall improvement of rural archives work [J]. Archives of China, 2021 (2): 32-33.

[11] Wang Ping, Li Yuling. Dilemma and breakthrough of socialized utilization of traditional village archives [J]. Archives and construction, 2021 (3): 31-36.

[12] Tang Jingxia. Serving rural grass-roots social governance and Promoting rural vitalization in an all-round way -- Thoughts on agricultural and rural archives work in Yiyuan County [J]. Shandong archives, 2020 (6): 74-75.

[13] LV Jing. Discussion on rural archives work in the new era [J]. Heilongjiang archives, 2020: 47.

[14] Wang Jian, Yu Qilin. Grasp the guidance and sing the "main melody" of service -- Zhangjiagang City creates a new model of file service and rural vitalization[J]. Archives and construction, 2021 (3): 52-54.

This page intentionally left blank

Subject Index

This page intentionally left blank

Author Index