ICSI 2022

The 13th International Conference on Systematic Innovation

Proceedings

Dates: October 15-16, 2022
Conference Venue: National Tsing Hua University, Hsinchu, Taiwan
(On-site & On-line Meetings)

Organizers:
International Society of Innovation Methods (I-SIM)
Society of Systematic Innovation (SSI)
National Tsing Hua University (NTHU) Local Host

Co-Organizers:
Ministry of Science and Technology (MOST)
Ministry Of Education (MOE)
National Taipei University of Technology (NTUT)

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Email: service@i-sim.org
ISBN 978-986-98016-9-0

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The organizers of the International Conference and Global Competition on Systematic Innovation (ICSI/GCSI) are pleased to present the proceedings of the 13th conference and the Program of Innovative Project Competition which include 44 papers and 9 finalist innovation projects. Authors and participants are from 14 countries/regions. This event is especially valuable during this difficult and unprecedented prolonged pandemic period of 2020-2022.

This conference is co-organized by International Society of Innovation Methods (I-SIM), Society of Systematic Innovation (SSI), National Tsing Hua University, and the International Journal of Systematic Innovation (IJoSI) and several supporting institutions. Whether the papers included in the proceedings are work-in-progress or finished products, the conference and proceedings offer the authors opportunities to disseminate the results of their research and receive early feedback from colleagues, without the long waiting associated with publication in peer-reviewed journals. On the other hand, the presentations and the proceedings do not preclude the option of submitting the work in an extended and finished form for publication in any peer-reviewed journal. Best papers and projects from the conference will be invited to submit full papers to IJoSI (SCOPUS) and Computers & Industrial Engineering.

The organizers are greatly indebted to a number of people who gave their time and efforts to make the conference a reality, especially the faculty and staff of IE department under the leadership of Chairman Chien-Wei Wu and Chair Professor Wei-Chang Yeh. The list of organizations and working team who have contributed tremendously to create this conference are acknowledged at the end of this program brochure. There are more contributors who are beyond the list.

The conference is a leading international conference in the world in the field of innovation methods/SI/TRIZ typically having one of the best quality programs and most papers presented in the fields. Due to pandemic, this conference is held with the both modes of on-line and on-site operations. Participants in Taiwan are encouraged to attend the meetings on-site yet all remote participants are attending on-line. Cisco WebEx is used as the platform for on-line meeting for best accessibility by all international participants.

We are confident that you will find this conference very rewarding. If there is anything needing assistance, please feel free to communicate with the Secretariat at icsi2022@i-sim.org. We are here to serve you.

With best regards,

D. Daniel Sheu, General Chair, the 2022 ICSI/GCSI
President, International Society of Innovation Methods
Honorary President, Society of Systematic Innovation
Editor-in-Chief, the International Journal of Systematic Innovation (IJoSI)
Area Editor, Engineering Design and Innovation Methods, Computers and Industrial Engineering
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2022.10.15

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Building an innovative high-standard market platform for the Guangdong-Hong Kong-Macao Greater Bay Area Economy

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Abstract

This paper discusses the economic and commercial importance of building an innovative high-standard market platform in the Guangdong-Hong Kong-Macao Greater Bay Area, and its comprehensive legal rules and responsibility governance.In terms of consolidating the basic system of market economy and ensuring fair market competition. It is necessary to clarify the obligations and responsibilities of the innovative market platform of the Guangdong-Hong Kong-Macao Greater Bay Area, and to strengthen the motivation and ability of education and publicity of market platform subjects to fulfill their obligations.The sound development of the market platform in the Guangdong-Hong Kong-Macao Greater Bay Area must take into account both "governance" and "innovation".Finally, we discuss that the foundation of market platform construction in the Guangdong-Hong Kong-Macao Greater Bay Area is to develop an innovative high-end and intelligent advanced real economy capacity.

Keywords: Governance and fair competition , Guangdong-Hong Kong-Macao Greater Bay Area, Innovative market platform

1, Introduction

The construction of an innovative high-standard market economy platform for the Guangdong-Hong Kong-Macao Greater Bay Area will enhance the market economic business operation model of the Greater Bay Area and create greater commercial value.In the construction process, it is necessary to more improve the legal regulation of market economy platform and the trust and credibility of market reputation.The construction of the market platform in the Greater Bay Area is an important cornerstone for national economic development in promoting innovative development, seizing the commanding heights of international competition and building social security.In order to ensure the sustainable and sound development of the Greater Bay Area market platform, we must build a logical credit system of the Greater Bay Area market platform, a legitimate and reasonable system for weighing data security and social value, clarifying the reasonable boundary of the platform main responsibility, and maintaining the economic basic system to consolidate the fair market order.

In ensuring the responsibility of fair competition in the Greater Bay Area market governance and innovation, we must be clear about relevant legal principles, tort liability and consumer security obligationy. We should improve the market platform by requiring main bodies to perform obligation motivation and ability, to strengthen the market platform subject to inform users with information integrity and education with fully cognitive attention to "should know information", carefully making consumer decisions.

The sustainable governance and innovation development of the market platform in the

Guangdong-Hong Kong-Macao Greater Bay Area must be based on the principle of inclusive and prudent regulatory concept, regular data governance, clear responsibility of market platform subjects, innovation-oriented market competition incentives, and the development of innovative high-end and intelligent advanced real economy.

This paper will detail the basic system of the above high-standard market platform construction of the Greater Bay Area.

2. Construction of an innovative high-standard market economic platform in the Guangdong-Hong Kong-Macao Greater Bay Area

(1) The market platform of the Guangdong-Hong Kong-Macao Greater Bay Area has changed economic forms and business models

1.It can optimize the market mechanism of resource allocation in the Greater Bay Area.

Over the past ten years or more, the global Internet platform economy has been booming, and the market platform model has become an important organizational way for enterprises' production and operation, forming a new economic form under the support of information technology and digital technology. Greater big bay area market platform economy development will change the traditional trade mode and division of labor, with the help of big data, artificial intelligence, cloud computing and other modern information technology, intensify resource gathering and participation, effectively reduce information search cost, accelerate the speed of the big bay area currency circulation, improve market trading and production efficiency, drive domestic consumption in the big bay area.

2.It can achieve the mutually beneficial commercial value of the Greater Bay Area.

Under the market platform economy model of the Greater Bay Area, big data becomes a factor of production, and computing power and algorithms become necessary conditions, which breaks the time limit and physical space distance.Using Metcalf's law to advocate that "network value grows at the square rate of users", the business model of the Greater Bay Area market platform guides the supply and demand from power confrontation to mutual beneficial sharing, and group value and individual utility complement each other.

(2) The market platform of the Guangdong-Hong Kong-Macao Greater Bay Area must be fully regulated by law

1. It increases the complexity of Greater Bay Area law application.

From the legal positioning, the big bay area market platform is not only the information center or trading place in the whole market trading process,it is also the link of upstream and downstream, the seller of the third party or the fourth party, through the display information, resource allocation, matching transactions, open source innovation, and sharing value services, as the party really involved in the specific legal relationship.In various industries in the Greater Bay Area, we should abide by laws related to market platform economy, including Anti-Unfair Competition Law, Law on the Protection of Consumer Rights and Interests, Food Safety Law, Price Law, Advertising Law, E-commerce Law, and Network Security Law[1]. Due to the market platform economy model in the Greater Bay Area, there are a large number of users being difficult to measure, and it is difficult for the limited judicial resources to fully protect the rights .At the same time, in the litigation of related contract acts and infringement, the dispute handling and liability judgment involving the third-party

liability subject is bound to be more complicated than when the subject of litigation is limited to the plaintiffs and defendants.In addition, because the third-party platforms in the Greater Bay Area market involve increasingly diversified trading categories, their dispute handling is significantly more difficult in professional knowledge judgment, legal interpretation, application order of special law and general law, which needs to be studied in advance and take precautions for a rainy day.

2. It must enhance the importance of market trust and credibility in the Greater Bay Area.

After years of development, the big bay area market Internet platform throughout instant communication, social life, mobile payment, catering and entertainment, e-commerce shopping, transportation, housing, education, etc, has significant public infrastructure properties, the market enhances responsibility determination， trusts the sound development of credibility,and influences the construction of the big bay area.

(3) The market platform of the Guangdong-Hong Kong-Macao Greater Bay Area is an important cornerstone for ensuring national economic development

1.It is an important engine to promote innovation and development in the Greater Bay Area market.

From the perspective of national development, in the face of a new round of scientific and technological revolution and industrial revolution sweeping the world, new technologies such as big data, cloud computing, internet of things, artificial intelligence, and blockchain are constantly emerging. The construction of market platform economy in the Greater Bay Area has brought important opportunities for overtaking in China's manufacturing curve.The national 14th Five-Year Plan clearly points out that accelerating digital development, developing digital economy, and promoting digital industrialization and industrial digitalization are our focusing directions.It can be predicted that digitalization will inject new impetus into the whole country and even the world.In the 2019 Government Work Report manifests that "the State adheres to inclusive and prudent supervision, supports the development of new business forms and new models, promotes the healthy growth of platform economy and sharing economy"; in the 2020 Government Work Repor tindicates that " the State supports the innovation and development of platform enterprises, enhances international competitiveness, while standardizes development in accordance with the law and improves digital rules[2].〞 We will strengthen anti-monopoly and prevent disorderly expansion of capital, and resolutely maintain a fair competition market environment, which guides the direction for the economic development and governance of market platforms in the Greater Bay Area.We can refer to the Implementation Plan of Zhejiang 〝High-quality Development and Construction of Common Rich Demonstration Zone (2021-2025),〞 which points out that "adhering to equal importance to development and norms, establishing and improving the platform economy governance system, and promoting the platform economy for high-quality development and high-quality life services"[3]. Digital economy has become a new engine leading the high-quality development of the market platform economy in the Greater Bay Area, which is of greater significance to the digital prosperity of the Guangdong-Hong Kong-Macao Greater Bay Area.

2. Building the Guangdong-Hong Kong-Macao Greater Bay Area is to seize the commanding heights of international competition.

From the perspective of international competition, the global rise of the market platform economy in the Greater Bay Area will go to the center of the world economic stage, becoming the embodiment of a country's technical level and comprehensive competitiveness of business model, and also the main battlefield for the major-country game.Before 2009,it is only Microsoft,and now a platform economy of Top10 enterprises with global market value has risen to 7, including 5 in the United States (Apple, Microsoft, Amazon, Google, Facebook) and 2 in China (Tencent and Alibaba).At present, seven platform economy enterprises' market value of about $10 trillion, including the five platform economy enterprises' market value of about $8.6 trillion, China's two platform economy enterprises' market value of about only $1.4 trillion,which implies that China's platform economic strength is still a

considerable gap, so the Greater Bay Area market platform economy construction is highly promising.

3. The Guangdong-Hong Kong-Macao Greater Bay Area is to build a castle for social security.

From the perspective of social security, if the market platform economy of the Greater Bay Area actively fulfills its social responsibilities, its security role on the public society can also be geometrically amplified.For example, Alipay continues to carry out a series of public welfare measures, such as health code, ant forest, anti-fraud investigation, barrier-free services, interest-free loans, consumer vouchers, charity fundraising, poverty alleviation, disaster relief, and common prosperity fund, which is to provide an important force of positive energy for economic and social harmony and stability.

(4) Governance of the market platform economy in the Guangdong-Hong Kong-Macao Greater Bay Area

1. Building a credit system based on the Greater Bay Area market platform logic.

The Internet platform in the Greater Bay Area market will meet the needs of consumers for a better life through new technologies, new models and new relations for a better life, make the production and marketing behavior more human, greatly shorten the transmission distance between supply and demand, and promote the improvement of market operation efficiency in the Greater Bay Area.In the face of the overall macro market in the new era of intensified competition, consumption chain shortens and will guide some enterprises to strategic short-sighted, we must prevent in "should not save time of quality control process copy shortcut," prevention from causing fake and shoddy goods flooding the market, reduce and prevent product quality infringement disputes to avoid endangering the Chinese society bein g already fragile integrity of trust foundation.

2.Should weigh the legitimate and reasonable system of market data security and social value in the Greater Bay Area.

In the operation of the market platform economy in the Greater Bay Area, higher requirements must be put forward for the rapid evaluation of the credit level of market entities, extending from the credit investigation system under the traditional economic model, and the market platform economy model in the Greater Bay Area is based on big data , rebuilding the basis of social integrity.In recent years, data gradually evolved into the core elements of market platform economy competition, we should take precautions, governance and prevention for big bay area market platform, platform and users, platform and government about the use of big data disputes, avoiding big bay area market derivative "data island"，"data barriers", exploiting the "data collection〞 of the most familiar strangers, "algorithm discrimination" and a series of disputes. Governance maintenance of big bay area market platform economy with core business model of legitimacy and rationality reflects the economy mode of data flow and data protection with a balanced system.

3. should clarify the reasonable boundary for the responsibility of market platform subjects in the Greater Bay Area.

With the rapid development of the market platform economy in the Greater Bay Area, we should pay attention to the main responsibility of the market platform enterprises in the Greater Bay Area.The subject of responsibility is the leading role in the maintenance of market order. The identity of the responsible subject must be determined before confirming the legal and compliance behaviors of the parties in the economic environment of the market platform in the Greater Bay Area, so that the sustainable and benign development of the market economy in the Greater Bay Area could be guaranteed .Under the Legislation Act, by which[4]·China's laws generally should have passed three trials, but the E-Commerce Law had started the legislative process since December 2013 and promulgated and implemented on January 1,2019, after four deliberations. After the introduction of

the law, the judicial practice and theoretical circles still added discussions.Among them, paragraph 2 of Article 38, the derivative market platform subjects of the law on "joint and several liability, supplementary liability, corresponding responsibilities", "unfinished obligations and direct infringement" and "audit obligations and security obligations", which are yet to be the Guangdong-Hong Kong-Macao Greater Bay Area market platform to improve e-commerce transactions.
4. Should maintain the market order for fair competition in the Greater Bay Area.

From the perspective of fair market competition, the market platform economy in the Greater Bay Area is helpful to promote the market competition of merchants in the Greater Bay Area, and the fair competition of merchants in the Greater Bay Area leads to the intensified competition of market platforms in the Greater Bay Area.According to statistics, there are more than 20 Chinese platform enterprises with market value / valuation of more than US $10 billion, and the top platform enterprises have spread in developed areas, such as Jingdong, Baidu, Meituan, Byte, Didi in Beijing, Alibaba and Ant Group in Zhejiang, Tencent in Shenzhen, Pinduoduo and other representative platform enterprises in Shanghai.The majority of businesses can operate or build their own websites on multiple platforms at the same time, or sell on online platforms and on offline physical stores at the same time, and merchants can transfer between the platforms with extremely low cost and convenient operation. These fair competition conditions should be well maintained.Under the fair market mechanism, an enterprise has its benign instinct to be better and stronger. In the process, it takes technological innovation, quality service and social responsibility to promote the benefits of social groups.However, some of the views believe that the larger platform is the "culprit" of the market order problem, producing differences in understanding between "bigger" process and "dominant" result.From the perspective of administrative law enforcement, the current Anti-monopoly Law"[4.] ,the protection of the social competition system, is the public law property; and the Anti-Unfair Competition Law emphasizes the protection of competitors and is the private law property.We should apply relevant laws and regulations to adjust and maintain market competition relations, so as to promote the independent innovation power of market platform enterprises in the Greater Bay Area, avoid unfair market competition due to the regulatory level gap of different subjects, and do a good job in the early work of fair competition ethics governance for the market platform economy in the Greater Bay Area.

III. Responsibility of the market platform in the Guangdong-Hong Kong-Macao Greater Bay Area

(1) Relevant legal principles for the principal responsibility of market platforms in the Greater Bay Area

1. make clear the tort liability for the network platform.

According to the civil code of the network platform of tort liability, mainly embodied in the "haven principle" and "red flag principle", which can be understood as the big bay area market platform, we should play the role of "gatekeeper", operators fulfill the obligation of attention, take necessary measures of careful identification and authentication, pay attention to certification, trademark, quality assurance and other key information audit . The Greater Bay Area market platform cannot ignore or shirk the obvious infringement; but if the market platform earnestly fulfills the duty of care or necessary measures, it shall be exempted.

The "Haven Principles" quote Article 1195 of the Civil Code: " If a network user uses network services to commit infringement, the right holder has the right to notify the network service provider to take necessary measures such as deleting, blocking and breaking links.The notice shall include

prima facie evidence of the infringement and the true identity information of the right holder.After receiving the notice, the network service provider shall transfer the notice to the relevant network user in time and take necessary measures according to the preliminary evidence and service type that constitute the infringement; if the necessary measures are not taken in time, it shall be joint and jointly liable for the expansion of the damage with the network user."

"Red Flag Principles" quote Article 1197 of the Civil Code: "If a network service provider knows or should know that the network user uses his network services to infringe on his civil rights and interests and does not take necessary measures, he shall bear joint and several liability with the network user".

We should publicize the above two business legal principles to the enterprise subjects of the market platform in the Greater Bay Area.

2. Should define the attributes of responsibility for consumer life-and health-related security obligations.

Goods and services related to the life and health of consumers, mainly including health preservation, drugs, insurance, etc., involving personal and property safety attributes. Paragraph 2 of Article 38 of the Electronic Commerce Law standardizes the performance of safety guarantee obligations of the market platforms, but all parties have different arguments on the liability attributes of the market platform.In the process of four rounds of legislative deliberation, after the transformation from "joint liability" to "supplementary liability" to "corresponding liability", the scope of "corresponding responsibility" has become a point of discussion in judicial practice and theoretical circles.On the other hand, in the corresponding penalties, Article 83 of the E-commerce Law clarifies the administrative responsibility of the market platform, and distinguishes the administrative obligations and civil obligations of the market platform, which is an innovation to adapt to the new business forms of the e-commerce market platform.

Section 38 of the E-Commerce Act provides that :

Paragraph 1: "If an e-commerce platform operator knows or shall know that the goods or services sold by the operators in the platform do not meet the requirements of ensuring personal and property safety, or otherwise infringe on the legitimate rights and interests of consumers and does not take necessary measures, he shall bear joint and several liability with the operators in the platform according to the law".

Paragraph 2: "For commodities or services related to the life and health of consumers, if e-commerce platform operators fail to fulfill the audit obligations of the operators in the platform or the safety obligations of consumers and damaging consumers, they shall bear corresponding responsibilities according to law".

The corresponding penalty is reflected in Article 83 of the E-commerce Law:

"If the e-commerce platform operators, in violation of Article 38 of this Law, fail to take necessary measures for the platform operators infringing on the legitimate rights and interests of consumers, or the platform operators without their qualification obligations or security obligations, the market supervision and administration department shall order them to correct and can impose a fine of not less than 50,000 yuan but not more than 500,000 yuan. If the case is serious, they shall be ordered to suspend business for rectification and impose a fine of not less than 500,000 yuan but not more than 2 million yuan".

From the judicial judgment, whether the market platform assumes civil tort liability lies in whether to fulfill its due responsibilities. Comprehensive summary of the "December 2018 of Yu Zhifu and Guangzhou Tzu Pharmaceutical Chain Co., Ltd." and other online shopping contract disputes[6] ,in June 2019 of the "Shanghai Xinyi Bailuda Pharmaceutical Co., Ltd. v. Shanghai Bang Medical Information Technology Co., Ltd."[7], and in December 2019 of "extreme sports web celebrity Wu Yongning fell dead of network infringement dispute"[8] , basing on these examples, the main view of

the court is as follows:

(1) Civil liability and administrative liability in violation of Article 38 should be treated differently.Administrative liability is mainly enforced by regulatory authorities; for civil liability, the judicial system still adopts the fault principle of traditional tort liability, whether the market platform constitutes the liability of civil infringement.

(2) Article 38 of the E-commerce Law is the extension of Article 37 of the Tort Liability Law in cyberspace. Whether the market platform is responsible completely depends entirely on whether it is responsible. And the content of security guarantee obligations generally should only include audit, notification, deletion, blocking, disconnection and other measures.

From the perspective of general understanding, the platform and merchants should not be regarded as "community", and the platform should assume independent responsibility in breach of security obligations.The main views are:

（1）The civil obligations of the market platform include audit obligations and security obligations, corresponding to different obligations.The audit obligation lies in the authenticity and legality of the business qualification and content, goods and services; the security obligations mainly consider the warning degree of the market platform and the assessment of the ability, and the relevant specific standards should be summarized and set in practice.

(2) The liability for breach of audit obligations, generally considered a supplemental liability.Violation of security obligations should not assume joint and several liability, but its specific liability attributes should be analyzed according to the actual situation. Basing from the level of theoretical interpretation, it will be more reasonable to define the responsibility for the breach of security obligations as a share of the responsibility, the responsibility for the breach of security obligations is an independent responsibility established for the violation of legal reasons, which is its own responsibility.

(2) Motivation and ability of market platform entities in the Greater Bay Area to fulfill their obligations

1.The motivation of market platform entities in the Greater Bay Area to fulfill their obligations must be continuously improved.

Under the operation mode of market platform, the number of merchants, store commission and so on are the decisive factors of profit, so it is reasonably difficult to determine the intensity of market platform entities to the performance of audit obligations and security obligations. Market platform in objective form has been responsible to its duty, but if the infringement dispute still assumes its subjective motivation which is not fully imagined, so that the business behavior still has "should review", the user's rights and interests still have "should not protect" room, for moral criticism, its responsibility to be lack of objective basis should be given understanding.

2.The ability of the Greater Bay Area market platform entities to perform their obligations must be continuously enhanced.

Market platform management covers the whole process of pre-audit, in-process monitoring and post-disposal. Artificial intelligence, machine learning and algorithm technology are taken as the main means, and relevant content is combined with manual audit.It is necessary to understand objectively, in the face of the number of market platform merchants more than millions, even if the technical means are advanced with 24-hour all-weather monitoring and investigation, coupled with limited human resources, objectively it is still difficult to exhaust the means to solve invisibl edanger and full coverage investigation, so it is necessary to constantly enhance the technical service ability.According to public data, Taobao has settled in tens of millions of merchants, Pinduoduo 6 million merchants, Jingdong millions of merchants, and the market platform has ultimate limited ability to perform its duties.On the other hand, the merchants settled on the market platform involve thousands of industries, and it is

difficult to grasp the industry knowledge required by different product business forms, and it is the top priority to fully fulfill their duties.In case of an infringement dispute, the market platform may constitute a direct infringement and causal relationship between failing to fully fulfill its obligations and the damage consequences.Admittedly, based on the protection of the legitimate rights and interests of consumers, if the market platform is aware of the infringement of user rights and interests, but fails to take necessary measures, it will be joint and jointly liable in accordance with Article 1195 and 1197 of the Civil Code and Article 38 of the E-Commerce Law.If consumers are difficult in proving evidence and cannot prove that they know that the goods or services provided by the market platform are dangerous, they can consider reversing the burden of proof and give the burden of proof to the market platform, that is, to strengthen the constraints of liability after the event to fulfill the main responsibility of the market platform.

(3) Asymmetry between the obligation of market platform entities in the Guangdong-Hong Kong-Macao Greater Bay Area and known information

1. Strengthen the regulation of market platform subjects' information in the Greater Bay Area.

For consumers, the big bay area market platform has the natural advantage of mastering business information, so we should ask the market platform to strengthen the management of business, in the process of information collection, sorting and inform, real information disclosure, making clear to the relevant rights and obligations terms, delivering real, complete, reliable information, solving the problem of information asymmetry, improving the transparency and trust of the market platform.

2. Consumers in the limited reason will ignore what they should know information.

The hypothesis about the rational degree of fact that economic individuals receive information, in 1970, Lucas, Sargent, etc., put forward the "rational expectation theory" (Rational Expectations), believing that each economic behavior subject always tends to start and make rational decisions from its own interests, based on all the information obtained.In 2003, Sims proposed the "Rational Inattention" (rational neglect theory), saying that because of the large cost of considering all information, economic actors will choose to deliberately ignore part of the information and will only make limited and rational decisions.In the big bay area market platform business model, web information display and format contract for improving the efficiency of trading activities, but compared with paper, web page with prompt notice function is not enough to attract reasonable attention of consumers, and the convenience of market platform transactions to induce consumers rush behavior and impulse decision, which causes users to "should know information" into "rational neglect", business score, rights and obligations, jurisdiction and other important information is in the state of "not attention".

In practice, sometimes there are market platforms that do fulfill the obligation of notification, or even highlight the display, but when faced with infringement disputes, consumers still claim that the market platform does not fulfill the duty of reminder and attention.In particular, objectively, consumers know the information, but in order to avoid their own mistakes in the dispute, they still claim that the market platform did not fulfill the obligation of notification, so that the ownership of responsibility can not be fairly determined.A typical case is that in the credit business of the market platform, the complainants have generally been included in the collection list, but in order to achieve the purpose of interest reduction, extending the debt term and reducing the repayment amount, the dishonest claims that the market platform fails to inform the interest rate level and repayment term information before the loan.At the time of the construction of the Guangdong-Hong Kong-Macao Greater Bay Area, we should educate consumers to be fully aware of the "information" that should pay attention to the market platform and make prudent choices of consumption decisions.

IV. Governance and innovation of the market platform in the Guangdong-Hong Kong-Macao Greater Bay Area

(1) Adhere to the concept of inclusive and prudent supervision.

From the perspective of national development, international competition, technological innovation and social security, the market platform economy of the Guangdong-Hong Kong-Macao Greater Bay Area is of great positive significance and needs to develop healthily in a sound environment.The market environment of the platform economy in the Greater Bay Area needs to be jointly maintained by the platform subjects, merchants, consumers and regulatory departments.In the future, the supervision and governance of the market platform in the Greater Bay Area should adhere to the concept of inclusiveness and prudence, and implement this concept into the treatment of each market platform. Under the principle of bottom-line supervision, it should leave enough space for the development of the market platform economy in the Greater Bay Area.We should take positive incentive as the principle to supplement appropriate punishment, maintain fair and orderly big bay area market environment, encourage the big bay area market platform enterprises to increase investment in independent innovation for both consumer rights and interests protection and concept education. The big bay area market platform economy maximizes positive effect and promotes the big bay area market platform participants with enhancing social well-being.

(2) Research on relevant data governance rules should be strengthened.

As the core element of the market platform economy of the Greater Bay Area, big data is related to the basic guarantee of credit system, fair market competition, privacy and other security.We should continue to improve the top-level design of big data governance, especially to obtain consensus on solving key issues such as the determination of data ownership, the establishment of data circulation rules, and the trade-off of data protection and development.At the same time, we will promote the platform and regulatory departments to deepen the integration of information system and share big data resources, and build a public-private cooperation trust mechanism between the government and the market so as to improve digital-driven administrative efficiency.

(3) The responsibility boundary of the platform subject should be reasonably clarified.

The responsibility of market platform entities should be more clearly defined. As the market platform economy of the Greater Bay Area promotes the transformation of trading mode, it is its due obligation for market platform entities to undertake the necessary active review and security obligations, but the scope of obligations of market platform subjects should be reasonably defined.We propose to take the principle of assuming our own responsibility, stimulating the internal driving force of the platform subjects to perform their duties to a greater extent, guiding businesses to constantly improve the quality of product manufacturing and service, and advocating the concept of healthy and righteous rights protection.

(4) An innovation-oriented and fair market competition environment in the Greater Bay Area should be created.

Market competition is a necessary condition for effective Pareto Optimality. We should build a rich and diversified market platform ecology in the Greater Bay Area to achieve micro-dislocation development and win-win macro-level cooperation.We should promote innovation as the main value orientation of anti-monopoly, reasonable application of the "anti-monopoly law " ," unfair competition law ","consumer rights and interests protection latoining" and other legal means of comprehensive constraints to guide different market platform subject to benign competition, making the economic cake bigger, jointly promoting the prosperity and development of the big bay area market platform

economy.

V. Conclusion: The foundation of the innovative high-standard market platform construction in the Guangdong-Hong Kong-Macao Greater Bay Area is the development of the high-end and advanced real economy

The construction of guangdong big bay area in Hong Kong and Macao should refer to the national "difference" planning development direction, focusing on the development of product circuit, biomedicine, artificial intelligence, electronic information, life, health, electric vehicles, advanced materials, new energy, environmental technology, health technology, high-end equipment and other new kinetic energy industry of the real economy[10].

In terms of digital industry construction in the Guangdong-Hong Kong-Macao Greater Bay Area, we should focus on emerging digital industries and enterprises such as smart technology, blockchain, big data, 5G,6G, industrial Internet, cloud computing and Beidou satellite[11].+, focusing on building "hardware + software + platform + service interactive feedback" of the full process of fully perfect industrial ecology, establishing upstream, middle and downstream key vertical integration of related industries, enhancing the cooperation of enterprises, schools, research institutions, joint research technology innovation and its application, actively building guangdong big bay area flagship digital enterprise innovation industry ecological base of perfect high-end advanced real economy, this is the foundation of the construction of guangdong big bay area of innovative high-standard market platform[12.13.]。

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PERCEPTION OF VR-BASED SAFETY TRAINING PLATFORM IN JEWELRY INDUSTRY IN HONG KONG

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Abstract

Hong Kong's jewelry industry remains basically a handicraft industry. However, it brings up physical damage concerns during metal casting. In addition, there is a lack of highly-skilled craftsmen to inherit experience and techniques by the next generation. With the emerging advanced technology, VR based training platforms have been applied in different aspects of education and especially efficient and safe for high risk working processes. This paper will study (1) challenges faced by jewelry industry, (2) occupational hazards in metal casting, (3) training modes of metal casting and (4) VR training platform for metal casting.

Keywords: jewelry industry; metal casting; Virtual Reality; safety training platform

I. INTRODUCTION

Hong Kong's jewelry industry is a central hub of pure gold items globally. In 2019, the industry comprised 220 manufacturing establishments and 3,360 import and export establishments, employing a total of 14,980 people. [1]

During the manufacturing process of jewelry, metal casting is a high risk process and especially dangerous to junior workers. While Hong Kong's jewelry industry remains basically a handicraft industry, manufacturers are required to obtain metallurgical knowledge and highly skilled technique in metal casting in order to prevent potential occupational safety hazards during metal casting, including skin hazard, respiratory hazard and vision hazard. To protect manufacturers and maintain a productive labour force, regular and sufficient training is essential for the manufacturers.

With the advanced emerging technology, one of the latest technologies, VR has been applied in different high-risk industries to provide a safe and regular training platform for workers. A VR based training platform provides manufacturers with hands-on, practical training of metal casting in a safe virtual environment, workplace productivity and safety can increase. Hence, a study of the application of VR based training platform in the jewelry industry becomes essential and concerning.

This paper will discuss the following sections: Section II of this paper reviews the background and challenges of the jewelry industry in Hong Kong. Section III represents the potential hazards of metal casting while Section IV focuses on discussing the training modes for craftsmen in the jewelry industry. Section V discusses the possibility of applying a VR training platform in the jewelry industry.

II. CURRENT PROBLEMS AND CHALLENGES IN JEWELRY INDUSTRY

To investigate the possibility of implementing VR based training platforms for the metal casting process in the jewelry industry, it is important to gain an understanding on the industry pain point and then tackle the problems.

The result of an online survey with 53 respondents shows the problems experienced by the jewelry industry in Hong Kong. Most of the factories are encountering similar issues in skilled human resources.

Lack of skillful craftsmen diminishes the quality of jewelry and the production output directly. A comparison could be done between the larger-scaled and smaller-scaled factories to show the situation. The knowledge transfer within a larger company might be easier since more training staff are available which is capable of providing regular training. However, smaller companies do not have enough human resources for conducting training because the skillful craftsmen have to focus on the production of jewelry. With the help of emerging advanced technology, VR based training platform could be a way to solve the problem.

A. Manpower Shortage

From the result of the survey, over 60% of respondents think there is a manpower shortage on high-skillful craftsmen (Fig. 1). Most of the skillful craftsmen are seniors who are about to retire. In general, the seniors are responsible for the main part of the manufacturing process. The worker with less experience seldom participates in the main process because of their poor technical skills (Fig. 1). Metal casting in jewelry requires high precision in the craftsmanship which will affect the company branding directly. Thus, the top management will not allow inexperienced workers involved in the main process to ensure the quality. In this way, only the seniors are familiar with the main process. In addition, the turnover rate of junior workers is usually high because they are not motivated to develop a career in the casting industry. It will become difficult to transfer the experiences and skills to junior workers (Fig. 1). Usually, the seniors are retired before the junior master the skills. In the end, there will be no skillful craftsmen and full of workers with little experience.

The main problem is to spend time on finding other skillful craftsmen to provide training to the junior worker. In a worst-case scenario they have to pause the production for training new staff which will suffer a great loss.

B. Operation Cost

The increase in operation cost will affect the manpower indirectly. Over 80% of respondents think that the cost of raw materials and transportation fees are increasing (Fig. 1). To save the cost, the factories tend to hire younger generations with no or little experience at a lower price because it is difficult to hire skillful craftsmen, who have been working in the industry for a while and their monthly salary is very high in the current state. Unless the factories are willing to pay a higher price, the skillful craftsmen will not leave their current job.

The result also shows that it is not difficult to attract the younger generation (Fig. 1). Only 21% of respondents suffer from these problems. There are still many fresh graduates in the market who would like to enter the jewelry industry. This would be an opportunity and the factories should hold on to these valuable assets. The only problem is how to motivate the younger generation to pursue a lifelong career in the jewelry industry. New technology like VR based training platforms could help attract the younger generation.

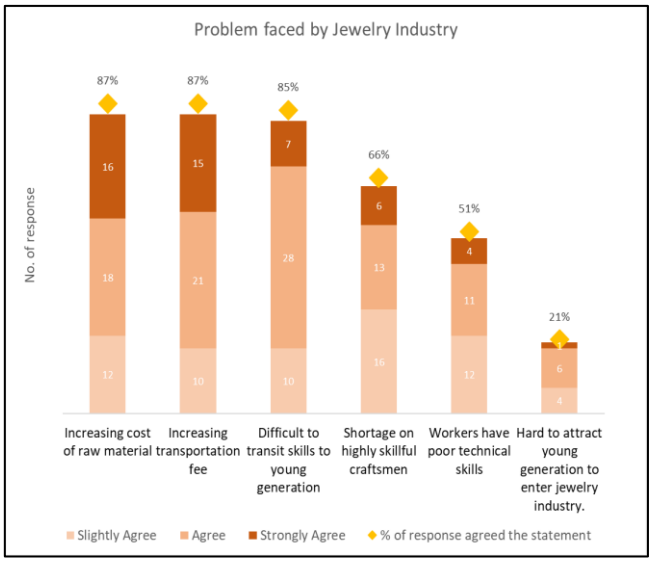

Fig. 1. Problem faced by Jewelry Industry

III. OCCUPATIONAL SAFETY HAZARDS IN METAL CASTING

In jewelry fabrication process, metal casting is an traditional production method to fabricate the metal products, like ring, necklaces, bracelets and other luxury accessories, with complicated shape and features [2]. However, the fabrication process, from melting, pouring, cooling, cutting, grinding to finishing, involved several potential occupational safety concerns as the workers could be operating an extremely high temperature of molten metal is poured into a casting mould in the shop floor [3, 4]. Foundry workers may be adversely affected by the following occupational safety hazards which can result in injuries, illness and death without appropriate training and practical experience [5].

The following major hazards in metal casting includes A) skin hazard B) respiratory hazard and C) visual hazard.

A. Skin hazard

When transferring molten metal from a furnace or ladle, the temperature could be in the region of 800℃. Skin hazard may be triggered due to the splashes of melting and pouring of molten metal [6]. In addition, technicians are exposed to heavy metals, such as copper, cadmium and chromium, which are chronic poisoning to skin [5]. Based on the survey, a majority of respondents (81%) agree that skin hazard is a common occupational hazard to the jewelry technicians.

B. Respiratory hazard

During jewelry making, foundry workers are exposed to air pollutants including smoke, dust, Respirable Suspended Particulate Matters (RSPM) and heavy metals [5]. Prolonged exposure to excessive contaminants can result in lung diseases. In the survey, most of the respondents (96%) agree that respiratory hazard is a common occupational hazard to the jewelry technicians.

C. Visual hazard

Cataracts may be caused as protective darkening goggle is not provided to the works or protection level of goggle might not be appropriate [6]. According to the survey, 91% of respondents agree that visual hazard is a common occupational hazard to jewelry workers.

IV. TRAINING PLATFORM

Comprehensive training sessions are necessary to keep the workers safe. In this research, the survey focuses on two general training modes: traditional training mode and novel training mode in order to investigate an efficient training tool to eliminate occupational safety hazards.

A. Traditional Training Platform

Traditional training modes normally are face-to-face, including one-way (e.g. with video-delivered, talk, seminar) and interactive type (e.g. workshop, apprenticeship, visits).

According to the survey result, workers are more familiar with traditional training mode and it is easy to catch up the knowledge (Fig. 2). In addition, the workers believe that one-way delivery training is not efficient. Workers prefer interactive training mode, which is more efficient.

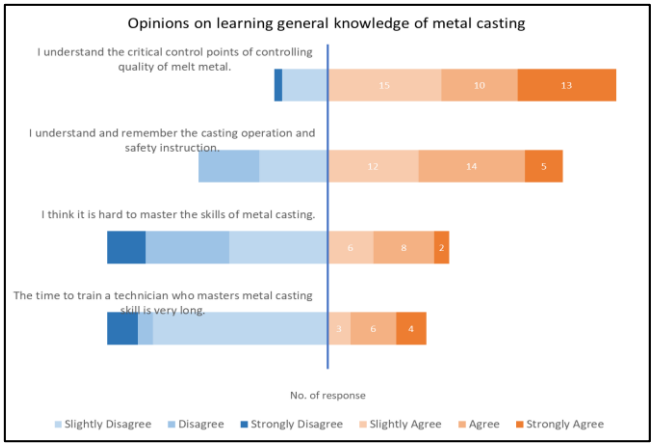

Fig. 2. Workers attitude to traditional training mode

B. Novel Training Platform

Despite of face-to-face traditional training, the novel training mode and new technological tools are generally acceptable and add value to the industry. Novel training mode can be face-to-face or hybrid mode. It usually incorporates new immersive technologies, like internet, VR, MR, AR, mobile apps, webinar, ZOOM workshop. Novel training mode offers off-site training, which provides a time-and-place flexibility.

Based on the survey, most of the workers have heard about novel training mode (Fig. 3) and the efficiency of novel training is recognised by the workers (Fig. 3). However, workers are unfamiliar with the operation of new technology tools (Fig. 3) and they have difficulties in using new technology tools, like mobile apps, headset and console.

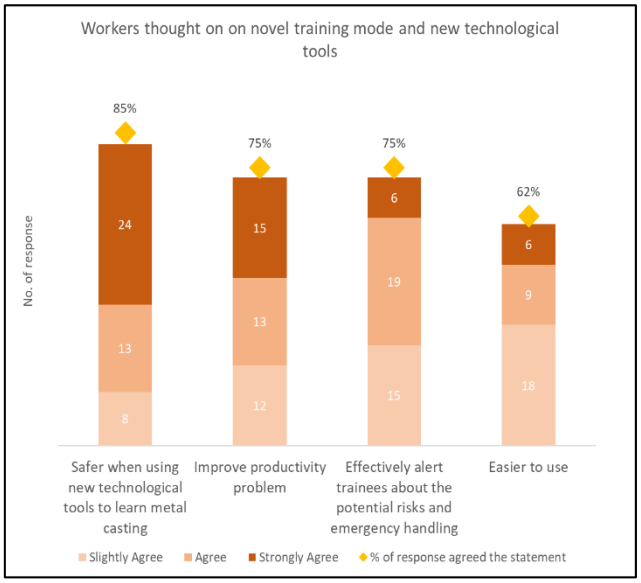

Fig. 3. Workers thought on novel training and new technology tools

V. VR TRAINING PLATFORM

To investigate the possibility of enhancing VR based training platforms to the jewelry industry, it is important to understand whether the workers are ready to shift from traditional training mode to novel training mode. A study would be carried out to find the foreseen uncertainty of implementing a new training mode. Workers from various backgrounds will have different experiences with VR technology. The goal is to understand how to attract workers joining the VR based training.

A. Equipment

From the survey result, most people have heard about the term virtual reality (VR). VR technology evolved quickly recently which can be commonly seen in PC, smartphone and gaming industry. Most of

the workers should have a basic knowledge of virtual reality hardware (head-mounted display, game console) and its software (audio system, sensors and warning system). Thus, when providing VR training it is not necessary to spend too much time on explaining the technology.

Nevertheless it is not surprised that many of the workers know how to operate the VR equipment. Most of them do not have hands-on experience . It is rare for workers to own personal VR equipment. When the factories introduces the VR training, it is important to let the worker have some hands-on experience with the equipment for adaptation. Research shows that not everyone is suitable for using VR because of motion sickness, such as nauseous feeling and dizziness [7]. It could be the first time for workers using VR equipment. The side effects of VR to individuals should be assessed first to determine whether they can adapt to the virtual environment.

Most of the respondents think there is too much equipment or facilities needed to set up for the introduction of a VR training platform. In fact, only the base station needs to be set up, and the calibration program will guide the operator step by step. Once the operator ensures the connection of headset and controller, the training program is ready to use. The whole setup should be within 10 minutes. Simple and straightforward guidance should be prepared to quell the concern from the workers.

B. Experience with VR tools

Currently VR based training platforms are not popular in the industry. Only a few factories, which are in large scales. Usually only factories with larger scale can provide this kind of training resources.

Many of them agree VR can simulate the real-life industrial environment (Fig. 4). As the training can be conducted repeatedly, the worker will be more familiar with the process and become confident to work after VR training (Fig. 4). This can minimize the chance of generating products with poor quality due to lack of experience. A metal casting process usually takes time. Sometimes, the product with poor quality cannot be sold to the market even after undergoing the rework process. It is not cost effective to produce something without value. VR training platform could be a suitable tool to prevent this problem from happening.

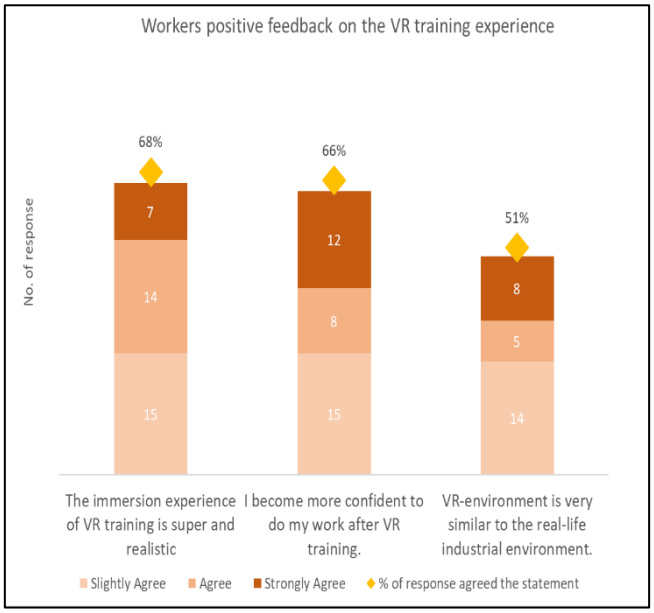

Fig. 4. Workers positive feedback on the VR training experience

Over 70% of respondents share similar issues during VR training. Based on their experience, the sensors usually respond very slowly with the actions (Fig. 5). When using VR it should be aware that there should be no interference between the environment and tracking system. Table 1 summarized the interference on tracking system using different technologies:

TABLE 1. Comparison between different tracking system [8]

Technologies	Accuracy	Precision	Interference
Acoustic	Low	Low	Acoustic interference
Electromagnetic	High	High	Interference with metal objects
Inertial	High	Low	Gravaition Interference
Mechanical	High	High	N/A
Optical	High	High	Ambient Light and infrared radiation

Choosing suitable VR tools is crucial to the user experience. One should avoid choosing the VR tools which will be easily interrupted by the surrounding environment. This is the main reason for workers who feel the sensor respond slowly. Tracking system using optical technology are commonly found in the market. According to Table 1, optical performs well in both accuracy and precision. The workers must pay attention to the lighting when setting up the VR training environment. On the other hand, comparing with other technology, the complexity of hardware setup for VR with optical tracking system is lower which is favourable to a layman.

Furthermore, results from the survey show that it is not common for people to feel unwell or dizzy after wearing a VR headset for more than 30 minutes (Fig. 5). Research has shown VR tools should have ninety frames per second or above to reduce the chance of having motion sickness [9]. In other words, the refresh rate of the display has to be faster than the image processing time of one's brain to prevent dizziness. To avoid the chance of having motion sickness, VR tools with fps less than 90 should be prevented. Also, based on the survey result, the duration of the training session should be within 30 minutes since most people feel comfortable in this range (Fig. 5).

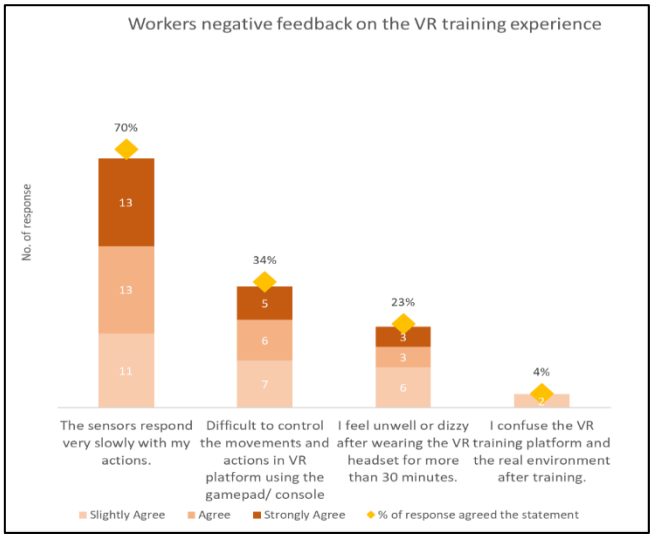

Fig. 5. Workers negative comments on the VR training experience

C. Factors affecting the adoption of VR-training kit

To investigate how to attract people to adopt VR based training platforms, the concerns from the industry needed to be identified first.

TABLE 2. Factors affecting the adoption of VR-training kit

Factors affecting the adoption of VR-training kit	% of response concerning the factor	Ranking
The ability of real industrial environment simulation	77.36	1
The cost of VR training kits	75.47	2
Ease of controlling the VR-training kits	60.38	4
Complexity of the preparation the VR software for specific process	54.72	5
Flexibility and Mobility of VR-training kit	64.15	3

From Table 2, most of the workers are concerned about whether the training platform can simulate the real industrial environment so they can have more confidence and become more skillful. A virtual environment should have more details to improve the similarity between real and virtual environment. Although most of the objects in the real industrial environment are not part of the training and interaction is not required, it is better to include them to improve the worker's experience which allows them to feel like they are in a real situation instead of a virtual environment.

Flexibility of VR training kits are also important to the worker. Sometimes the factories receive the order which requires additional functions. The production process might vary a little. A system should be structured, which provides autonomy to workers in constructing their own training based on their learning needs. This can also improve the training efficiency because the workers can skip the training which is not necessary and focus on the tasks they are working with.

VI. INTEREST OF USING VR-TRAINING PLATFORM ON METAL CASTING PROCESS

From the survey result, over 70% of the respondents are interested in using a set of VR training about technical skills in the metal casting process. It is a good sign to develop VR training platforms because people start to accept the application of new technology in the training.

Nevertheless, over 60% of the respondents expect high development costs and long development time (Fig. 6). The factories hesitate before adopting VR training kits. In Section V, it shows that development cost is one of the most concerns for the adoption. High cost with long development time will become the biggest obstacle. More funding should be provided to help the factories so VR based training platforms could be prevailed.

In addition, it can be perceived that a special room is required for adopting the VR training kit. Usually factories are full of miscellaneous items and they need to avert them when setting up an area for VR training. Otherwise, the one who wears the headset might hit the surrounding object easily and cause injury. On the other hand, there should be no obstacle inside the sensing area of the base station to ensure the sensor can have the best response.

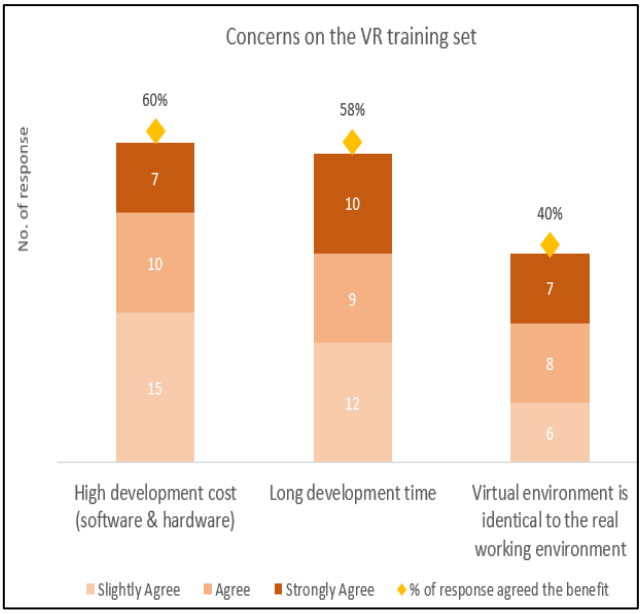

Fig. 6. Concern on the VR training set

Younger generations are valuable resources to the industry. To attract them to join the industry, VR training could be one of the selling points. Over 66% of the respondents found VR training interesting (Fig. 7). Unlike traditional training, VR training allows trial and error. They can explore the metal casting process themselves for better understanding. This can help them build up their own knowledge and apply it to reality. Failure is acceptable in VR training and this can encourage them to try more. This is what traditional training cannot achieve and the attractiveness of VR training. Moreover, the time for training new or young workers can be shortened (Fig. 7). There is no need to find experienced craftsmen to prepare learning materials. The workers can start the training on their own and they can practice repeatedly until they have confidence to perform the tasks in reality. This training mode is effective and no materials nor equipment will be destroyed due to lack of experience.

Nothing is more important than health and safety to workers during the production process. Section III mentioned different hazards and risks in the metal casting process. Over 60% of the respondents are confident that VR training can enhance the awareness of knowledge on OSH (Fig. 7). The training program might require the workers to wear Personal Protective Equipment (PPE) before proceeding to the process that is dangerous. The best way to enhance safety awareness is to develop a habit. Once they get used to wearing PPE, self-consciousness would be built up and they would feel weird without wearing PPE during the metal casting process.

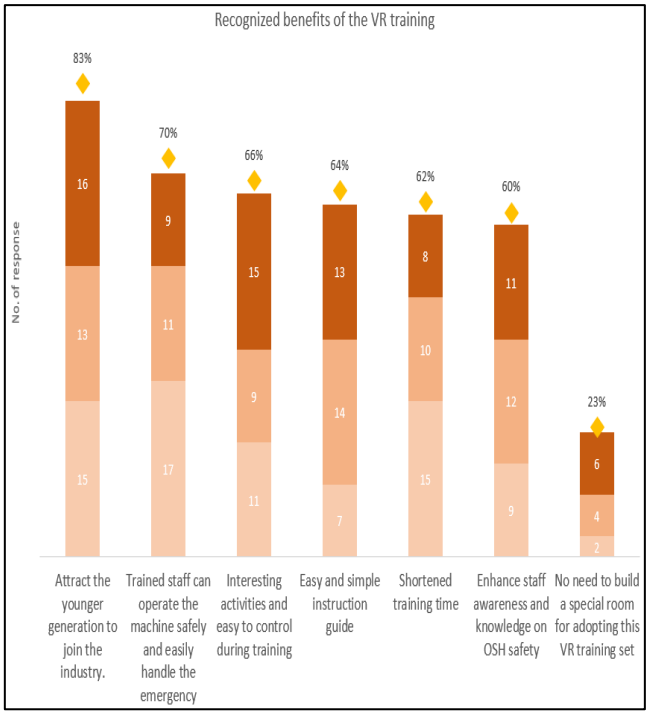

Fig. 7. Recognized benefits of the VR training

VII. CONCLUSION

This paper reviewed the challenges of the jewelry industry. The manpower shortage gap makes the factories difficult to sustain the business. Skillful craftsmen are aged and they are about to retire. However, it is not easy for a new or young staff to master the skills. There are not enough staff with competence to train the younger generation. VR based training platform could be the solution to alleviate the manpower shortage problems. Metal casting is a very dangerous process and the occupational safety and health issues should not be ignored. VR training platforms can make the worker become confident and skillful to minimize the chance of having an accident. It can also enhance their safety awareness to protect their health. Traditional training mode is not always effective. Sometimes, only one-way transfer of knowledge could be provided and not all the workers can have hands-on experience during the training. VR training platform as one of the novel training modes can overcome the drawbacks of traditional training mode and inherit its advantages as well. This paper also recommends the setup for a VR training platform based on the needs and concerns from the industry so to promote it to the jewelry industry. In the future, the research team will apply the VR technology and share the insights in the next paper.

ACKNOWLEDGMENT

The work described in this paper was fully supported by Hong Kong Metropolitan University Research Grant (No. 2019/1.9).

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Structural Simulation of the Claims for Devices

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Abstract

The problem of the interaction of patent law and TRIZ is considered in this paper. Su-Field analysis is applied from TRIZ tools. The European claim of the invention is used to describe the device. The claim is divided into technical features for structural simulation. Binary relationships are introduced between features to build hierarchy levels. As a result, an oriented graph is obtained, the nodes of which are features, and the branches show the subordination of features. The elements are at the top level, and the connections between them are at the middle level. The properties of elements and links are at the lower level. The physical operating principle of the device from the patent description is used for numerical evaluation of the structure. At the middle level of the hierarchy, features of interaction between elements are replaced by mechanical, thermal, electric, and magnetic fields from Su-field analysis. Further, the inventive fields are replaced by the dimensions of the physical quantities in which the fields are measured. For example, the dimensions of ampere, volt, watt, coulomb are used for electric fields, depending on the specific design of the device. The dimensions of physical quantities are given in the Bartini basis with two basic units time T and space L. Two-dimensional diagonal matrices are introduced to describe the weights of graph branches. A weighted and oriented graph mathematically describes the structure of the claim. The purpose of the simulation is to numerically compare the novelty of the claim with the prototype. The novelty coefficient is determined by the degree of asymmetry of the new solution and the prototype. The symmetric part is the inventive features included in the restrictive part of the claims. The inventive features included in the characteristic part form the asymmetry of the claims.

Keywords: invention, claims, novelty, simulation, Su-field analysis

1. Introduction

An important problem of technical design is the evaluation of inventive solutions. To compare inventive solutions, they must be formalized according to certain rules. One of the well-known methods of comparing formalized solutions is patent examination of inventions. The most structured part of the patent is the claim. Witz and Geisel (2017) indicate the claim has three parts: preamble,

transitional phrase and claim body. The claim body contains features, i.e. components, their connections and characteristics. In Russia and China, the European form of the claims is used, which has a restrictive and distinctive part. The restrictive part contains the features of the invention common to the prototype and the new solution. The distinctive part contains only the features of a new solution. The features of the invention are used for the mathematical patent model, according to which different indicators of the technical solution are evaluated.

In the work (Bushuev and Chepinskiy, 2007a), a probabilistic mathematical model is proposed, according to which the level of development of the technical system is estimated. A chronological sequence of inventions x_k is introduced, in which the invention x_{k-1} is the prototype for the invention x_k, k=0, 1, 2,... Then each invention can be considered as a state of a single-scale queuing system with waiting, which receives a random stream S_i of invention features. The features of the restrictive part come to the kernel for maintenance Ker x_k, and the features of the distinctive part form a queue Que x_k . The probability p_{ik}(Ker x_k) | $S_i \in$Ker x_k and the probability p_{jk}(Que x_k) | $S_j \in$ Que x_k, $i \neq j$ are entered. It is shown for $k \to \infty$ p_{jk}(Que x_k)$\leq$0.5 and lim p_{ik}(Ker x_k) = 1. The product of the probabilities of several features included in the kernel gives the kernel density $p(k)$. The product of the probabilities of several features included in the core gives the core density $p(k)$. The graph $p(k)$ gives a discrete S-curve (Altshuller,1999), according to which the level of technology development is estimated.

Weidong et al. (2020) propose a graph-based probabilistic patent evaluation model. In the model, the textual parts are combined with some structured parts of patents. The patent value is initially determined by the internal features of the patent. Given a patent o, the patent value v^o is initially formed by the features from the patent and exhibits a prior probability distribution. $v^o \sim p(v^o|D^o)$ where $o \in VO$ and D^o denotes some features extracted from the structured and unstructured parts of o. $VO=\{o_n\}$ where o denotes an object to be valued. Next patent values are changed by the values of the nodes that are associated with the patents.

In the work (Bushuev and Chepinskiy, 2007b), a structural model of the claims in the form of a graph is proposed. The nodes of the graph are the features of the device, and the branches are binary relations between the features. The structural scheme determines the strength of the claims $F = 1/n$, where n is the number of nodes of the graph. In the refined estimation of the strength of the formula, node weight functions are used, depending on the number of branches of the node.

The considered methods of stimulation have a disadvantage. The features of the claims are considered equivalent since the claims represent the device in a static stationary state. The importance of the features is found out in the dynamic state. The physical operating principle of the device is presented in the patent description, but not in the claims. The dynamic action of the device represents an unstructured part of the patent description. In TRIZ (Goldovsky and Weinerman, 1990), a simulation of the structure by an oriented graph consisting of substances S_i and fields F_j is

proposed. Mechanical, thermal, electric and magnetic fields are used. In the graph $F_1 \rightarrow S_1 \rightarrow F_2 \rightarrow S_2 \rightarrow \ldots F_i \rightarrow S_j$, the direction of energy conversion is shown by arrows. The nodes of the graph are not equivalent, but their numerical weight is missing. Differential equations are used to simulate a dynamic graph. In (Zaripova et al, 2015), for any node of the graph, the differential equation of thermodynamics $dQ = PdE$ is used, where dQ is the differential of the generalized work, P is the generalized force, and dE is the generalized coordinate. The graph model turns out to be dynamic, but it is redundant for patent protection of the device.

In TRIZ, the use of the theory of dimensions of physical quantities is also known. The inputs and outputs of the nodes of the graph are encoded by the dimensions of physical quantities in one or another basis. For example, in (Coatanéab et al, 2015) the MLT-basis (mass-length-time) is considered. The topology of a technical system is represented by a graph, the nodes of which are variables of three types: system variables, input and output variables. The branches of the graph are constructed according to the expert assessment of the cause-and-effect relationships. The graph matrix in the MLT-basis is used to check the reliability of the structural model and find nodes with a violation of cause-and-effect relationships. In (Bushuev and Kudriavtseva, 2019), the LT-basis (length-time) is used to numerically estimate the resource intensity of the graph. Shibayama et al (2021) propose a numerical evaluation of scientific documents on semantic text analysis. The novelty of the document is assessed by the frequency of references in the cited literature. However, such an estimate has weak validity for patents, since a patent can have only one reference to a prototype.

The aim of the work is to obtain numerical estimates for comparing a new solution and a prototype according to their patents. Let's pose the following search problem.

2. Problem statement

The new technical solution is specified in the patent description with the claim. The new technical solution is specified in the patent description with the invention formula. Therefore, the description and claim of the prototype invention are known. We will assume that the claim of the device has the following types of features:

a) the presence of structural elements;
b) the presence of a connection between the elements;
c) mutual arrangement of elements;
d) the form of the element, in particular, the geometric shape;
f) form of communication between elements;
g) parameters and other characteristics of the elements.

Let's divide all the features into three levels of hierarchy: the highest level includes features a), the middle level includes features b) and c), the lower level includes features d), f) and g). The set of

features is denoted by $\{D_i\}$, where i is the number of the feature, i = 1, 2,... We introduce the binary relation D_i R D_j, where R means that the attribute D_i does not exist without the attribute D_j, $i \neq j$. The binary relation establishes the subordination of features, which is indicated by arrows in the graph, and the nodes in the graph are the features of the device. Some of the D_i features are common to the new solution and the prototype. Common features are included in the restrictive part of the claims for a new solution. We denote the set of features of the prototype by $\{D_o\}$, and we denote the set of features of the new solution by $\{D_n\}$ where o and n are integers denoting the feature number. Then the restrictive part of the claims of the new solution will be equal to the intersection $\{D_o\} \cap \{D_n\}$ of the sets. We will consider the intersection as the symmetric part of the new solution-prototype pair. The set of features of the new solution-prototype pair is shown in Figure 1 where the symmetrical part is indicated in green. The distinctive part of the new solution forms the set $\{D_n\}$ - $\{D_o\} \cap \{D_n\}$. If $\{D_o\}=\{D_n\}$, then $\{D_o\} \cap \{D_n\} = \{D_o\}=\{D_n\}$, and such an invention has no novelty $\{D_n\}$ - $\{D_o\} \cap \{D_n\}=\{\emptyset\}$. In this case, the new solution and the prototype are completely symmetrical. Therefore, the inventor needs a minimum of information to get a new solution from a known prototype.

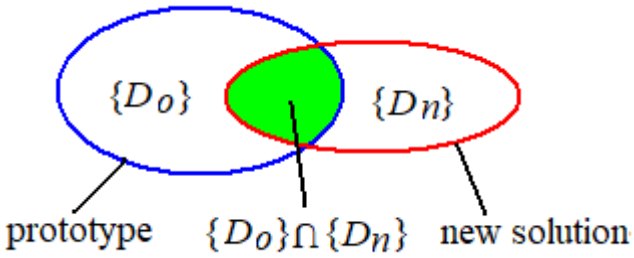

Figure 1. The set of features of the new solution-prototype pair.

This information is that the new solution and the prototype are completely symmetrical. A new solution turns out to be more asymmetric when the inventor has to generate more new information so that this solution can be reproduced. Thus, we will evaluate the degree of novelty by the magnitude of the asymmetry. In (), The paper (MacCormac, 1998) discusses in more detail the use of symmetry and asymmetry in science and technology.

3. Defining the similarity function

Brown (2021) considers the similarity function $S(A,B)$ of two objects A and B as a function f of three arguments three arguments

$$S(A,B) = f(A \cap B, A \setminus B, B \setminus A), \quad (1)$$

where $A \cap B$ are features belonging to A and B, $A \setminus$ B are features belonging to A but not belonging to B, $B \setminus A$ are features belonging to B but not belonging to A. For patent features, you can write $A \cap B$=

$\{D_o\} \cap \{D_n\}$, $A \setminus B = \{D_o\} - \{D_n\}$, $B \setminus A = \{D_n\} - \{D_o\}$ where object A is a prototype, in object B is a new solution. Equation (1) for the degree of symmetry E is written as

$$E = f(\{D_o\} \cap \{D_n\}) / [f(\{D_o\} \cap \{D_n\}) + \alpha f(\{D_o\} - \{D_n\}) + \beta f(\{D_n\} - \{D_o\})], \quad (2)$$

where α and β are some feature weights. It is necessary to take two steps to find the function f and the coefficients α and β. The first step is called structural simulation, and the second step is called dimensional simulation.

3.1 Structural simulation

We will show a structural simulation of some D_i features using a simple example. Let the claim of an optical device (Figure 2) be given: a radiation source on the optical axis of which a photodetector is installed. Let's make a block diagram of the claim. The scheme has two upper-level features D_1 - the radiation source and D_2 - the photodetector.

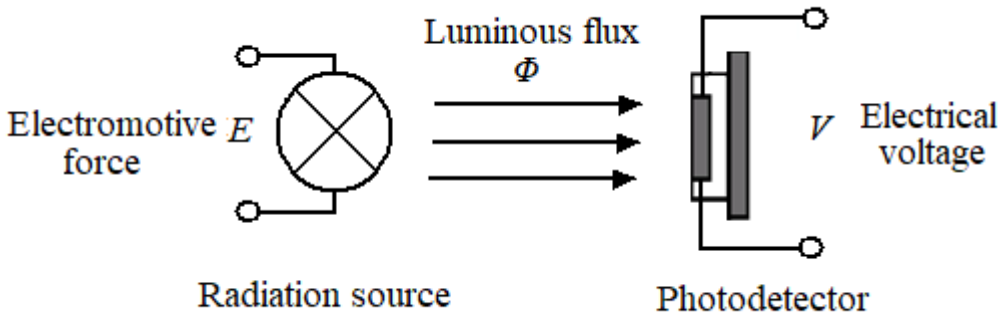

Figure 2. The design of the optical device.

Installation on the optical axis D_3 is a feature of an average level, since D_3 R D_1 and D_3 R D_2. A structural simulation of the claim is shown in Figure 3, where the graph of features and its nodes are shown on the left, and an equivalent Su-field structure is shown on the right. The nodes of the D_i graph are placed in circles; the directions of subordination are indicated by arrows. To obtain an equivalent Su-field structure, the description of the work and the design of the device in Figure 2 are used. Top-level features D_1 and D_2 are replaced with full Su-fields consisting of three elements F→Su→F. Such a structure has problems to detect (Petrov, 2014). The feature of the average level D_3 is replaced by the field F2, since the radiation field passes along the optical axis between the radiation source S1 and the photodetector Su2

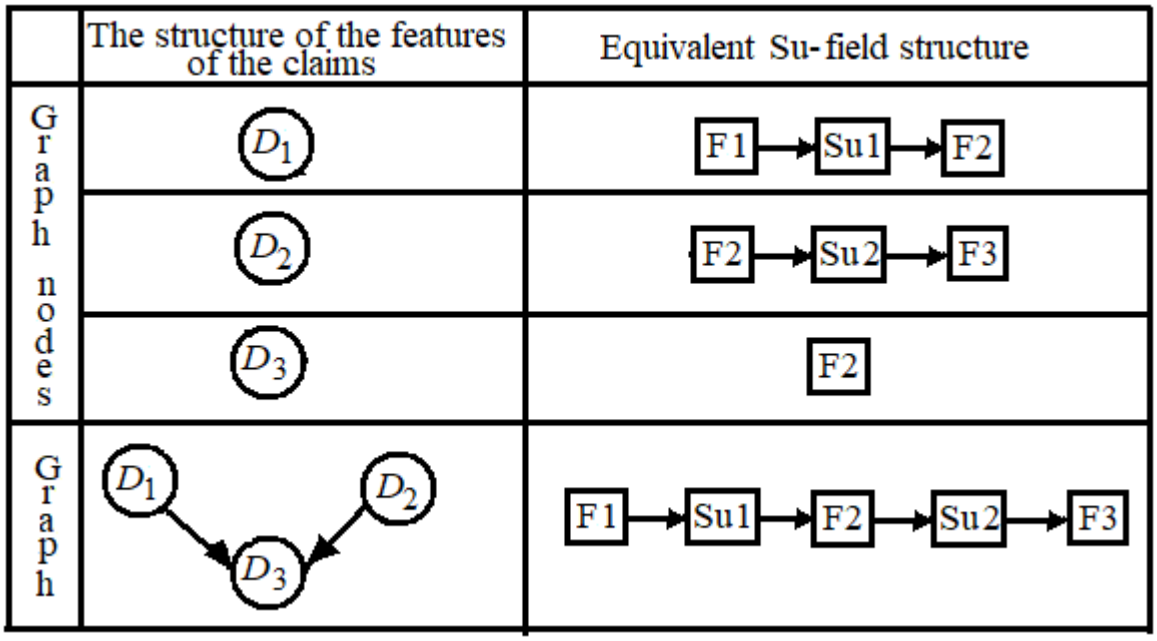

Figure 3. Structural simulation of an optical device, F1 - electric field, S1 - radiation source, F2 - radiation field or electromagnetic field, S2 - photodetector, F3 - electric field**.**

The final Su-field structure represents the complex Su-Field F1→Su1→F2→Su2→F3. If there is no D_3 feature in the claim, then the Su-field structure contains two complete unrelated Su-Fields F1→Su1→F2 and F2→Su2→F3. If there is no D_2 feature in the claim, then the D_3 feature disappears, only the D_1 Su-Field remains F1→Su1→F2. As you can see, the F2 field does not disappear. It defines the operational function of the radiation source.

3.2 Dimensional simulation

Numerical estimates of the features are needed to compare the prototype and the new solution. Su-Field analysis does not allow making such a comparison. Indeed, it is impossible to answer how much an electric field is better than a mechanical pressure field or a magnetic field is better than a thermal field. The paper (Bushuev and Kudriavtseva, 2019) shows how inventive fields of different types of energy can be numerically compared. In invention problems, the fields differ from each other in the physical quantities by which they are measured. In inventive problems, the fields differ from each other in the physical quantities by which they are measured. For example, the electric field can be measured in units of electric voltage, current, charge, field strength. Consider the radiation source D_1 in Figure 2 with the Su-Field F1→Su1→F2. The input electric field F1 is measured in EMF units, i.e. in volts. The output radiation field F2 is measured in units of luminous flux, i.e. lumens. In the Bartini system of kinematic quantities (Bartini, 2005), the EMF has a volt dimension $[L^2T^{-2}]$, and the lumen has the dimension joule/c $[L^5T^{-5}]$, where length L and time T are the basic units. We introduce matrices for the input and output values

$$EMF = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}, \Phi = \begin{bmatrix} L^5 & 0 \\ 0 & T^{-5} \end{bmatrix},$$

(3)

where EMF is the electromotive force at the input of the radiation source, Φ is the luminous flux at the output. We find the transfer matrix W_1 of the radiation source from Equations (3)

$$W_1 = \Phi\, EMF^{-1} = \begin{bmatrix} L^5 & 0 \\ 0 & T^{-5} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}^{-1} = \begin{bmatrix} L^3 & 0 \\ 0 & T^{-3} \end{bmatrix} \quad (4)$$

The input value of the photodetector will be the illumination E measured in lux, and the output value is the electrical voltage V in volts. The illumination E in the Bartini system has the dimension of surface power $[L^3T^{-5}]$. Therefore, the transfer matrix W_2 of the photodetector is equal to

$$W_2 = V\, E^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^3 & 0 \\ 0 & T^{-5} \end{bmatrix}^{-1} = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^{3} \end{bmatrix}. \quad (5)$$

The transfer matrix W_3 of the feature D_3 is equal to

$$W_3 = E\, \Phi^{-1} = \begin{bmatrix} L^3 & 0 \\ 0 & T^{-5} \end{bmatrix} \begin{bmatrix} L^5 & 0 \\ 0 & T^{-5} \end{bmatrix}^{-1} = \begin{bmatrix} L^{-2} & 0 \\ 0 & T^{0} \end{bmatrix}. \quad (6)$$

In Equation (6), it is assumed that the feature D_3 cuts out a part of the spherical luminous flux Φ, limited by the aperture S of the photodetector. The transfer matrix W_3 is the inverse matrix of the surface S. In the LT basis, the surface has dimension $[L^2T^0]$ or m^2. The dimensional simulation scheme is shown in Figure 4. The features of the claims D_i are given by the transfer matrices W_i. The transfer matrices differ from each other in exponents m and n with basic units L^m and T^n where m and n are integers.

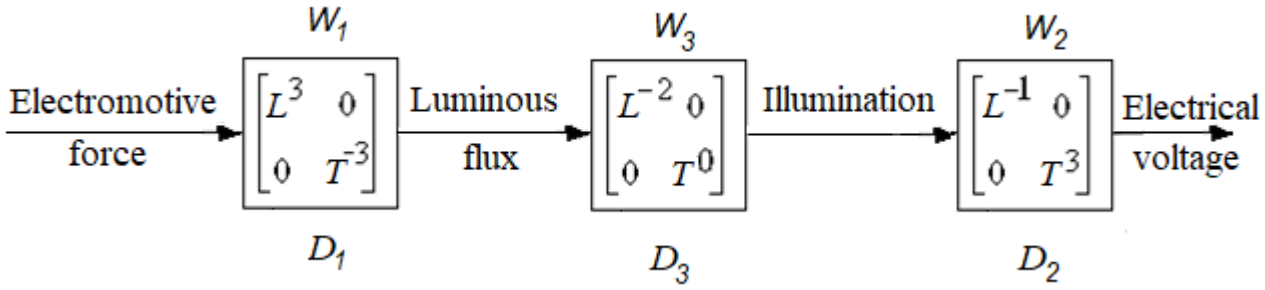

Figure 4. Graph of dimensional simulation.

Let's determine the resource intensity RI of the transfer matrices forming the nodes of the graph for dimensional simulation

$RI_i = \sqrt{m^2 + n^2}$ for $W_i = \begin{bmatrix} L^m & 0 \\ 0 & T^n \end{bmatrix}, RI_1 = \sqrt{(3)^2 + (-3)^2} = 4.24, RI_2 = \sqrt{(-1)^2 + (3)^2} = 3.16, RI_3 = \sqrt{(-2)^2 + (0)^2} = 2.0.$ (7)

The total resource intensity of the device is equal to

$$RI = \sum_{i=1}^{3} RI_i = 9.40. \quad (8)$$

The resource intensity *RI* will be used to calculate the function *f* in Equation (2). From a physical point of view, the resource intensity of the node W_i means the time and space resources spent on converting the input value into the output value.

4. Calculation of the novelty of the piezoelectric actuator

Let's choose a new solution protected in the invention piezoelectric actuator (Bystrov et al., 2009). The design of the actuator is shown in Figure 5. The actuator contains a composite converter 1, made in the form of a set of flat piezoelectric elements. The position sensor 2 consists of an inductive sensor 11 and a summing amplifier 12, which sends an error signal *Ve* to the input of the PI controller 4. The PI controller 4 supplies the *Vc* control signal to the high-voltage amplifier 5. The high voltage from the high-voltage amplifier 5 enters the converter 1 and creates a mechanical shear stress in the piezoelectric elements due to the reverse piezoelectric effect. The mechanical shear stress moves the rod 3 of the actuator.

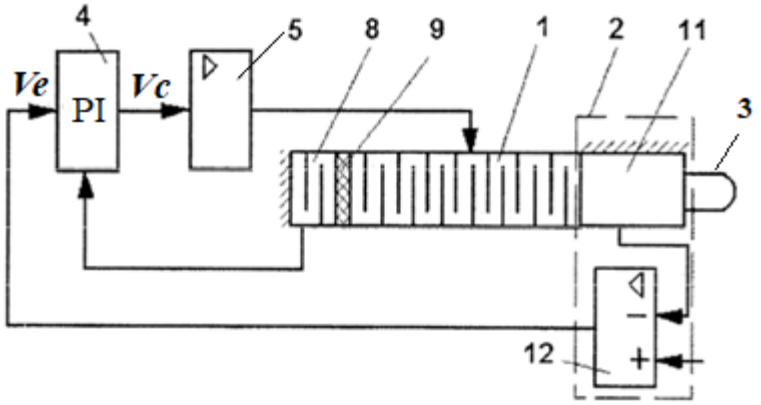

Figure 5. Piezoelectric actuator design.

The difference from the prototype (Shigeru, 1989) consists in the following features. The converter 1 is divided into two parts by an electrically isolated piezoelectric element 9. The piezoelectric element 8 of the isolated part is included in the feedback of the integrating amplifier of the PI controller 4. This piezoelectric element 8 is equivalent to an electric capacitor whose charge

depends on the mechanical shear stress of the converter 1 due to the direct piezoelectric effect (Katzir, 2006). Thus, the piezoelectric element 8 includes parametric feedback, which adapts the time constant of the integrating amplifier.

The graph of the structural simulation of the claims is shown in Figure 6. The features are indicated by the D_i symbols. The features of the restrictive part belong to the new solution and the prototype. The features of the distinctive part belong only to the new solution. We define transfer matrices for dimensional simulation. The input value of the converter 1 is the electrical voltage V. The voltage matrix in the LT basis is equal to

$$W_V = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}$$

The output value of the converter 1 is the mechanical shear stress, the matrix of which is equal to

$$W_P = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix}$$

We obtain the transfer matrix W_1 of converter 1

$$W_1 = W_P \, {W_V}^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}^{-1} = \begin{bmatrix} L^0 & 0 \\ 0 & T^{-2} \end{bmatrix}.$$

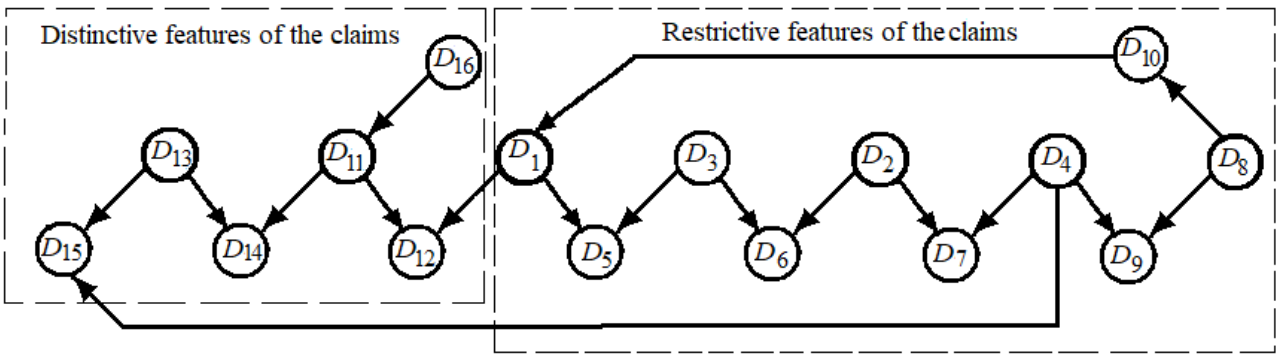

Figure 6. Graph of piezoactuator structural simulation, D_1 - converter 1, D_2 - position sensor 2, D_3 - rod 3, D_4 - PI controller 4, D_5, D_6 , D_{12}, D_{14} - mechanical connection, D_7, D_5, D_9, D_{10}, D_{15} - electrical connection, D_8 - high-voltage amplifier 5, D_{11} - electrically isolated piezoelectric element 9, D_{13} - piezoelectric element 8, D_{16} - electrical isolation of piezoelectric element 9

Similarly, we find the remaining transfer matrices. For the mechanical connection D_5 we have the Equation

$$W_5 = W_P \, {W_P}^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix}^{-1} = \begin{bmatrix} L^0 & 0 \\ 0 & T^{0} \end{bmatrix}.$$

The rod 3 is rigidly connected to the converter 1, therefore, the resource costs of time T and space L for transmitting the pressure field from the converter to the rod are zero. Next, the Equation for the rod has the form

$$W_3 = W_x\, W_P{}^{-1} = \begin{bmatrix} L^1 & 0 \\ 0 & T^0 \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix}^{-1} = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^4 \end{bmatrix}$$

where W_x is the matrix of the output displacement x of the rod 3. For the mechanical connection D_6 we have the Equation

$$W_6 = W_x\, W_x{}^{-1} = \begin{bmatrix} L^1 & 0 \\ 0 & T^0 \end{bmatrix} \begin{bmatrix} L^1 & 0 \\ 0 & T^0 \end{bmatrix}^{-1} = \begin{bmatrix} L^0 & 0 \\ 0 & T^0 \end{bmatrix}$$

since the input element of the position sensor 2 is rigidly connected to the rod 3. We find the transfer matrix W_2 of the position sensor 2

$$W_2 = W_V\, W_x{}^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^1 & 0 \\ 0 & T^0 \end{bmatrix}^{-1} = \begin{bmatrix} L^1 & 0 \\ 0 & T^{-2} \end{bmatrix}$$

where W_V is the matrix of the output voltage of the position sensor 2. The transfer matrix W_7 of feature D_7 is equal to

$$W_7 = W_V\, W_V{}^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}^{-1} = \begin{bmatrix} L^0 & 0 \\ 0 & T^0 \end{bmatrix}.$$

Let's define the transfer matrix of the feature D_{13}. Piezoelectric element 8 implements a direct piezoelectric effect, the input matrix of which is the pressure matrix, and the output matrix is the electric charge matrix. Therefore, W_{13} is equal to

$$W_{13} = W_Q\, W_P{}^{-1} = \begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix}^{-1} = \begin{bmatrix} L^1 & 0 \\ 0 & T^2 \end{bmatrix},$$

where W_Q is the electric charge matrix. PI controller 4 or feature D_4 has three connections, of which two are input connections D_7 and D_{15}, and one is output connection D_9. A typical circuit of a PI controller with an integrating amplifier is shown in Figure 7a) (Johnson and Moradi, 2005). Therefore, the PI controller 8 has two transfer matrices W_{41} and W_{42}

$$W_{41} = W_V\, W_V{}^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}^{-1} = \begin{bmatrix} L^0 & 0 \\ 0 & T^0 \end{bmatrix},$$

where the matrix W_{41} simulates the proportional part of the Pi controller 8,

$$W_{42} = W_V\, W_Q{}^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix}^{-1} = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^0 \end{bmatrix},$$

where the matrix W_{42} simulates the integral part of the PI controller 8.

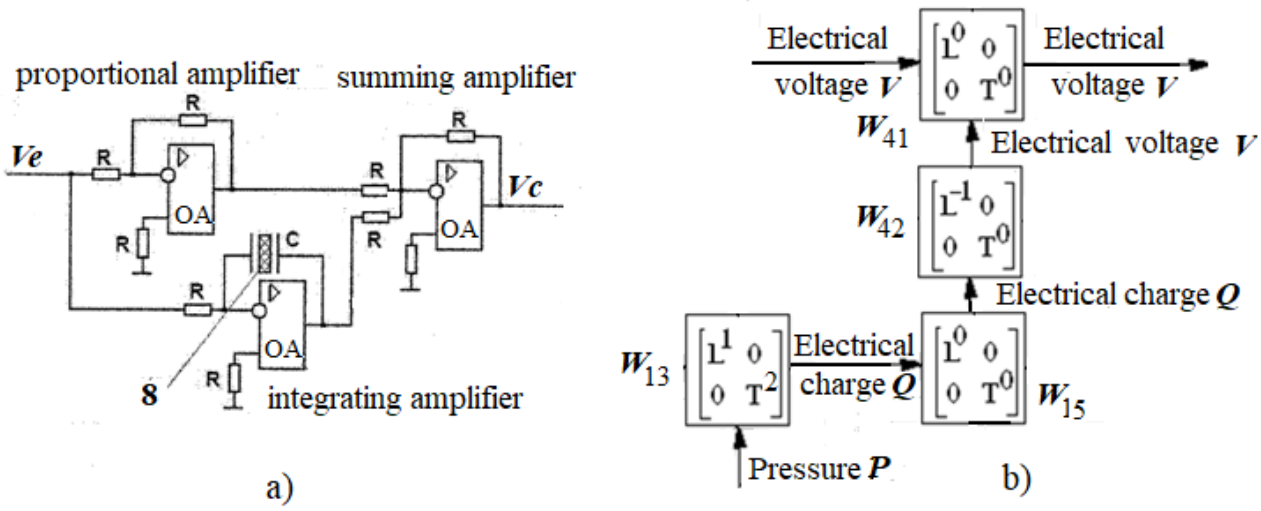

Figure 7. PI controller 4, a) electrical circuit, OA -operational amplifier, R - resistor, C - piezoelectric element 8, b) dimensional simulation circuit

The transfer matrices of features D_8, D_9 and D_{10} are the same and equal

$$W_8 = W_9 = W_{10} = W_V\, W_V{}^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}^{-1} = \begin{bmatrix} L^0 & 0 \\ 0 & T^0 \end{bmatrix},$$

since these features simulate the transmission of electric voltage V. The transfer matrices of features D_{11}, D_{12} and D_{14} are the same and equal

$$W_{11} = W_{12} = W_{14} = W_P\, W_P{}^{-1} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix}^{-1} = \begin{bmatrix} L^0 & 0 \\ 0 & T^0 \end{bmatrix},$$

since these features simulate the transmission of pressure P. The matrix W_{15} transmits an electric charge Q from the piezoelectric element 8 to the integrating amplifier 4, therefore W_{15} is equal to

$$W_{15} = W_Q\, W_Q{}^{-1} = \begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix}^{-1} = \begin{bmatrix} L^0 & 0 \\ 0 & T^0 \end{bmatrix}.$$

The D_{16} feature belongs to the lower level of the hierarchy. It characterizes the internal property of the piezoelectric element 9. In the Bartini system, the property of electrical insulation is measured in units of conductivity with dimension $L^{-1}T^{1}$. Therefore, the matrix W_{16} is equal to

$$W_{16} = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^1 \end{bmatrix}.$$

Now we can calculate the resource intensities RI_i of all transfer matrices W_i by Equation 7:

$RI_1 = 2, RI_2 = \sqrt{5}, RI_3 = \sqrt{17}, RI_{41} = 0,\ RI_{42} = 1, RI_5 = RI_6 = RI_7 = RI_8 = RI_9 = RI_{10} = RI_{11} = RI_{12} = 0, RI_{13} = \sqrt{5}, RI_{14} = RI_{15} = 0, RI_{16} = \sqrt{2}.$

Let the similarity function f of the set of features D_i be equal to

$f(\{D_i\}) = \sum RI_i.$

Then the similarity function for the features from the restrictive part of the claims is equal to

$f(\{D_o\} \cap \{D_n\}) = RI_1 + RI_2 + RI_3 + RI_{41} + RI_{42} + RI_5 + RI_6 + RI_7 + RI_8 + RI_9 + RI_{10} = 2 + \sqrt{5} + \sqrt{17} + 1 = 9.359.$

Then the similarity function for the features from the distinctive part of the claims is equal to

$f(\{D_n\} \cap \{D_o\}) = RI_{11} + RI_{12} + RI_{13} + RI_{14} + RI_{15} + RI_{16} = \sqrt{5} + \sqrt{2} = 3.650.$

We find the degree of symmetry E of the prototype-new solution pair from Equation 2

$$E = \frac{f(\{D_o\} \cap \{D_n\})}{f(\{D_o\} \cap \{D_n\}) + \alpha f(\{D_o\} - \{D_n\}) + \beta f(\{D_n\} - \{D_o\})} = \frac{9.359}{9.359 + 3.650} = 0.719,$$

where α and β are the weighting coefficients equal to 1. The set $\{D_o\}$-$\{D_n\}$ is empty, since all the features of the prototype are included in the new solution and $f(\{D_o\}$-$\{D_n\}) = 0$. In general, the set $\{D_o\}$-$\{D_n\}$ may be nonempty. Numerically we find the novelty coefficient

N=1- E= 1- 0.719= 0.281.

The novelty coefficient is in the range $0<N<1$, the greater the N, the greater the novelty of the invention. If the novelty coefficient is N=0, then all the features of the new solution coincide with the features of the prototype. A patent for an invention is not issued. The Ideal End Result (IER) is obtained when N =1. It is impossible to get the IER, since there is always at least one common feature. The name of the invention is a common feature of the prototype and the new solution. The name defines the function of the device. The value of the patent is modeled by novelty, inventive step, and other value determining parameters (Reitzig, 2003). Therefore, numerical estimation of novelty helps to find the value of the patent.

5. Conclusion

Structural simulation based on the claims of inventions makes it possible to establish a link between TRIZ and patent law. Substance-field analysis of the claims allows you to build models of the operating physical principle of devices. The costs of time and space resources for design are based on the model. The exponents m and n for L^m and T^n show the number of integrators and differentiators in time and space in a dimensional simulation of a dynamic model. The complexity of the model depends on the number of integrators and differentiators.

Some problems appear when simulating boundary conditions in the structural graph of the claims. For example, the features of the lowest level of the hierarchy have only one branch in the structural graph. In Figure 6, such a feature is D_{16}, i.e. the property of the electrical isolation of the piezoelectric element 9. Node D_{16} in the graph has one branch of communication with node D_{11}, therefore, feature D_{16} has only an output, but no input in dimensional simulation. The transfer matrix W_{16} cannot be found as the ratio of output to input. Therefore, we find the form of the matrix W_{16} directly from the Bartini LT-table by the physical dimension of the electrical isolation property. This property is measured in conductivity units with dimension $L^{-1}\,T^{1}\,1$ and resource intensity 1.41 for m = -1 and n =1. Also, other physical properties of the material can be indicated. For example, a magnetic material is determined by the property of magnetic permeability with dimension $L^{-2}T^{2}$. The viscosity property of a material in the SI system is measured in pascals multiplied by a second, and this property has the dimension $L^{2}T^{-3}$ in the Bartini system. Another way to describe a feature of a material is a physical effect that has an input and output. For example, a piezoceramic washer is used in a direct piezoelectric effect. The pressure P is the input, and the electric charge Q is the output. Then the dimension of the piezoelectric property is equal to $L^{3}T^{-2}/L^{2}T^{-4}= L^{1}T^{2}$. The inverse piezoelectric effect brings an inversion of $L^{2}T^{-4}/\ L^{3}T^{-2}= L^{-1}T^{-2}$, but the resource intensity remains RI=√5=2.236. It should be noted that the piezoelectric effect input may be the force F applied to the center of the ceramic washer, and not the pressure P applied to the end surface of the washer. This design of the device must be presented in the claims.

Simulation of methods of action on material objects is an unsolved problem. The features of the method in the claims are divided into three groups: the presence of actions; sequence of actions; the mode of performing actions, devices and tools necessary to perform actions. The dynamics of features in claims complicates dimensional modeling. For example, there is such a feature as steel heats up at a rate of 100 degrees Celsius per minute in the claims. The dimension of the heating rate in the Bartini system is $L^{5}\ T^{-5}$. Hence, we can find the transfer matrix for this action. However, the numerical value of 100 is not described in dimensional simulation.

Acknowledgements

This research was supported by Zhejiang Provincial Natural Science Foundation of China under Grant No. LGG19E070008 and was supported by Key Research and Development Project of Zhejiang Province under Grant No. 2019C04018.

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Evaluation of Shooting Forms Based on Human Pose Estimation

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Abstract

The technique of human pose estimation, as an emerging application of the newly developed computer vision technology, can identify the position coordinates of the joints of the human body from color images and thus can be used to recognize movements and evaluate forms. In this paper, based on the Open Pose, the method of human pose evaluation, we generate human poses in shooting videos and use the data of human movements and Euclidean distance to evaluate the shooting forms and calculate the corresponding movement scores to provide an objective reference for shooting training. The final average score of correct shooting forms obtained in this paper is 90.29, and the average score of incorrect shooting forms is 44.36, meaning that the method proposed in this paper can distinguish correct shooting forms from incorrect shooting forms and is of good applicational value.

1. Introduction

Basketball game, a comprehensive sport of its kind, is more competitive and skill-oriented. The key to a basketball game lies not only in the cooperation between players and the confrontation between opponents but also in the field-goal percentage. Various factors affect the percentage, such as technical movement, physical fitness, and psychological quality.[1] Among these factors, technical movement is the basis for field-goal percentage, and correct and standardized shooting is the key to improve shooting percentage.[2]

In recent years, the development of technology has provided a variety of convenient and objective technical means for shooting training, such as basketball stands that can move intelligently[3], VR-assisted shooting training[3], wearable auxiliary devices that can monitor shooting forms[3] and shooting tracking system[6]. These methods usually require additional hardware to assist shooting training, which may cause the problem of high cost or affect shooting forms. And as computer vision matures, the evaluation and monitoring of non-contact shooting forms based on images have also developed correspondingly[7]. These kinds of methods, through

the technology of human pose estimation, extract the movement data of crucial points of the human body from shooting videos to assist the analysis and evaluation of shooting forms, hence the advantages of non-contact and low cost.

2. Evaluation of Shooting Forms Based on Human Pose Estimation

The technology of human pose estimation is a branching application of computer vision. By using a neural network, it can estimate the position of critical points of the human body in color images and assemble them into the human skeleton. These methods can mainly be divided into two types: top-down direction and bottom-up direction. The difference between these two mainly lies in whether to detect the regions of the human body before extracting key points. The typical method of the former is Regional Multi-person Pose Estimation (RMPE)[8], and Cascaded Pyramid Network (CPN)[9] ,and the typical method of the latter is OpenPose[10]. The two methods have their own merits and demerits. The top-down method has higher accuracy but the slower operation. In contrast, the bottom-up method has faster operation because the number of people in the images does not affect the operation speed but lower detection accuracy.

OpenPose, a method of bottom-up multi-person pose estimation[10], estimates key points of human body and part affinity fields (PAF) in the color images through a two-branch neural network and assembles all the points into full body poses based on limb vectors in the PAF. This network operates fast and will reach 26 frames per second on the Central Processing Unit (CPU) after the optimization of the network structure by Osokin et al.[11], and will meet the demand for real-time video stream processing when running on devices with accelerated Graphics Processing Unit (GPU). Due to the convenience of engineering applications and the extension of subsequent applications, this paper uses the method of OpenPose for human pose estimation.

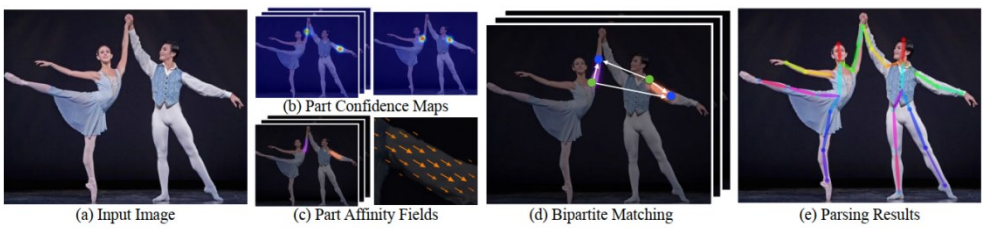


Figure 1 The working process of OpenPose[10]

In OpenPose, there are mainly 18 critical points of human body detected. In a shooting video, the camera shoots the players primarily from behind, and the key facial points are obscured, so the movement data of the rest of the key points are focused. In terms of the movements of shooting, OpenPose can capture complete and unblocked images of the upper and lower limbs, so it can accurately obtain the coordinates and the movement data of the limbs. The specific result of human pose estimation is shown in Figure 2.

Figure 2 Key points detected by OpenPose and human pose estimation

3. Evaluation of Shooting Forms

To align the human poses of the correct shooting forms with the incorrect ones and to take the midpoint of the line connecting the key points of the shoulder as the alignment point of human poses. Then align all the shooting forms to the midpoint of the image. Its result is shown in Figure 3.

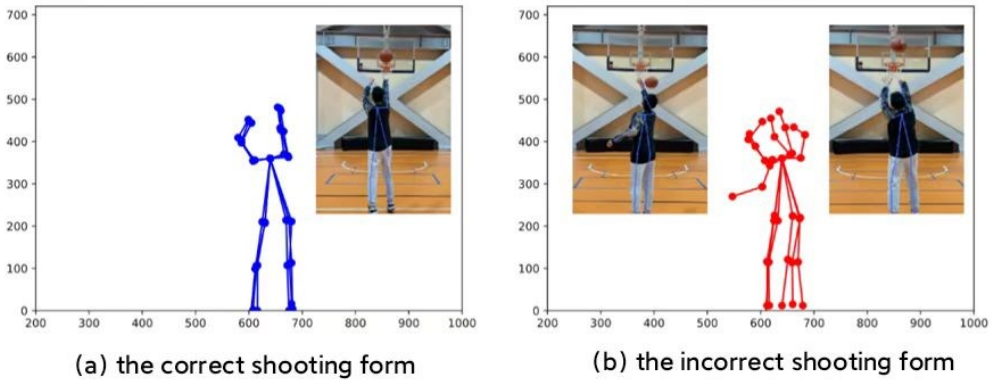
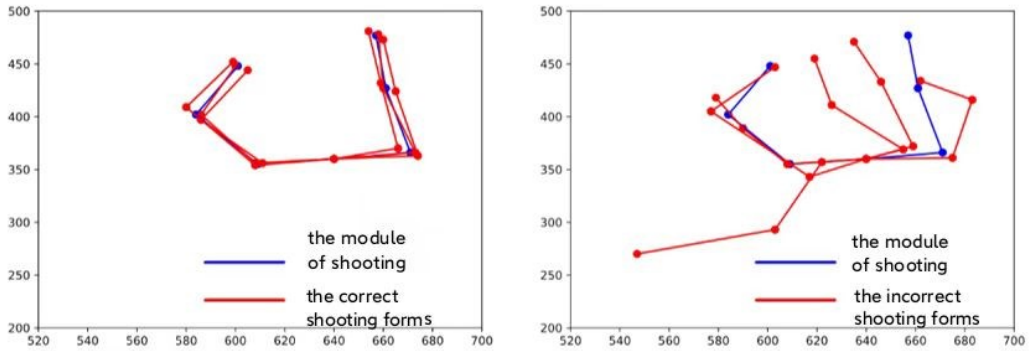


Figure 3 Different shooting forms

Figure 3 shows that the correct shooting forms are consistent in movements, and the human poses they show are similar: at the moment of shooting, the left arm is bent while the right arm is straight. However, in the wrong shooting forms, the human poses show apparent deviations, including the wrong form of casting with right hand and the non-standard one of inclining the right arm in shooting. Therefore, the evaluation of shooting forms and the scoring of movements can be based on establishing a module of the correct shooting forms.

The difference between various shooting forms is mainly related to the mode of movement of the upper limbs, so the movement data of the key points in the upper limbs are used for the evaluation of shooting forms. First, with all the movement data of upper limbs in the correct shooting forms as the original data, the shooting module with the average of coordinates of movement is established. Figure 4 shows the comparison between the module of shooting and the two different shooting forms.



(a) The comparison between the module of shooting and the correct shooting forms

(b) The comparison between the module of shooting and the incorrect shooting forms

Figure 4 The comparison between the module of shooting and different shooting forms

Finally, calculate the Euclidean Distance between the module of shooting and different shooting forms. Let the motion data of upper limbs of each shooting be $\boldsymbol{X}= (x_1, x_2, \cdots, x_n)$ and the data of the module of shooting be $\boldsymbol{Y}= (y_1, y_2, \cdots, y_n)$, among which n represents the number of key points in the upper limbs. The calculation formula of the distance between them will be as follows:

$$dist(\boldsymbol{X},\boldsymbol{Y}) = \sqrt{\sum_{1}^{n}(x_i - y_i)^2} \quad (1)$$

With the distance between the module of shooting and different shooting forms, the scoring of poses can be calculated by the following formula:

$$score(\boldsymbol{X}) = e^{-\frac{dist(\boldsymbol{X},\boldsymbol{Y})}{\alpha}} \quad (2)$$

In this formula, α is an empirical parameter and taken as 100, and the interval of the final scoring of forms is adjusted in accordance with the calculated distance. The calculated scoring of shooting forms is shown in Table 1, and the scoring of forms is based on a centesimal system.

Table 1 The scoring of different shooting postures

The Serial Number of Shooting Forms	1	2	3
The Correct Shooting Forms	87.86	91.59	91.42
The Wrong Shooting Forms	52.42	10.46	70.19

It can be seen that the scores for correct shooting forms are above 85 with an average score of 90.29, while the scores for incorrect ones are all below 80 with an average score of 44.36, indicating that the evaluation methods of shooting forms in the images shown in this paper can effectively distinguish between correct and incorrect forms, and are of instructional value for sports training.

4. Conclusion

With the application of OpenPose, a method of human pose estimation, this paper extracts the key points of the human body in the shooting videos and uses Euclidean Distance to calculate the distances respectively between correct or incorrect shooting forms and the standard shooting forms based on the movement data of upper limbs obtained, and then calculates the centesimal score by the corresponding formula. It can be seen from the final scores that the scores for correct shooting

forms are much higher than those of incorrect ones, indicating that the method proposed in this paper can effectively distinguish correct shooting forms from incorrect ones and can be well applied in practice, thus providing an objective basis and reference for standardized training of shooting forms.

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Application of Resources in FlexSim Modeling: Advantages and Drawbacks

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Abstract

The use of resources is an excellent concept for solving the contradiction problem in TRIZ methodology. However, it is always assumed that a proposed solution that uses external resources is elegant and perfect. This paper presents an example of simulation 3D modeling with FlexSim which shows that the use of external resources can give rise to inaccurate waiting times in a queue. We also provide an alternative process flow model in FlexSim to remove this drawback, and show that when solving the contradiction problem in TRIZ using external resources, we need to consider the function replacement of an object and consideration should also be given to the measurement of the performance of other objects. Finally, the ramifications of using an incoming customer to a queue as a trigger is shown to have similar effect to the use of patrolling officers to check for unattended parked cars in the street. A tentative solution is provided to enhance the efficacy of issuing parking tickets by a patrolling officer.

Keywords: Resource, 3D modeling, Process flow modeling, FlexSim, Waiting time.

1. Introduction

Resources provide functions; for example, water is a resource that can be used for fire extinguishing or as refreshment for animals and plants. Many resources can serve a given function. Fire can be quenched by both water and baking soda, meaning that baking soda can replace water in providing the function of fire extinguishing. Similarly, milk (from a cow or goat, for instance) can refresh animals and plants in the same way as water. In TRIZ, a function analysis of a product or process can be carried out to identify opportunities for using external objects or objects inside the system to replace the function of another object, so that fewer objects are required by the system to deliver a given function. One of the famous examples of the use of resources in TRIZ is the problem of overflow in painting (Deng, Lin, Tsai, and Lee, 2018) as shown in Figure 1. When air solidifies the paint, this causes the buoy to adhere to the paint. Eventually, the pump cannot detect when to stop pumping the paint into the container, causing the problem of overflow (Figure 1). After a function analysis, the external resource of gravity is used to replace the motor and pump to allow the paint to move by itself (Figure 2), which eliminates numerous parts of the system and makes the solution elegant.

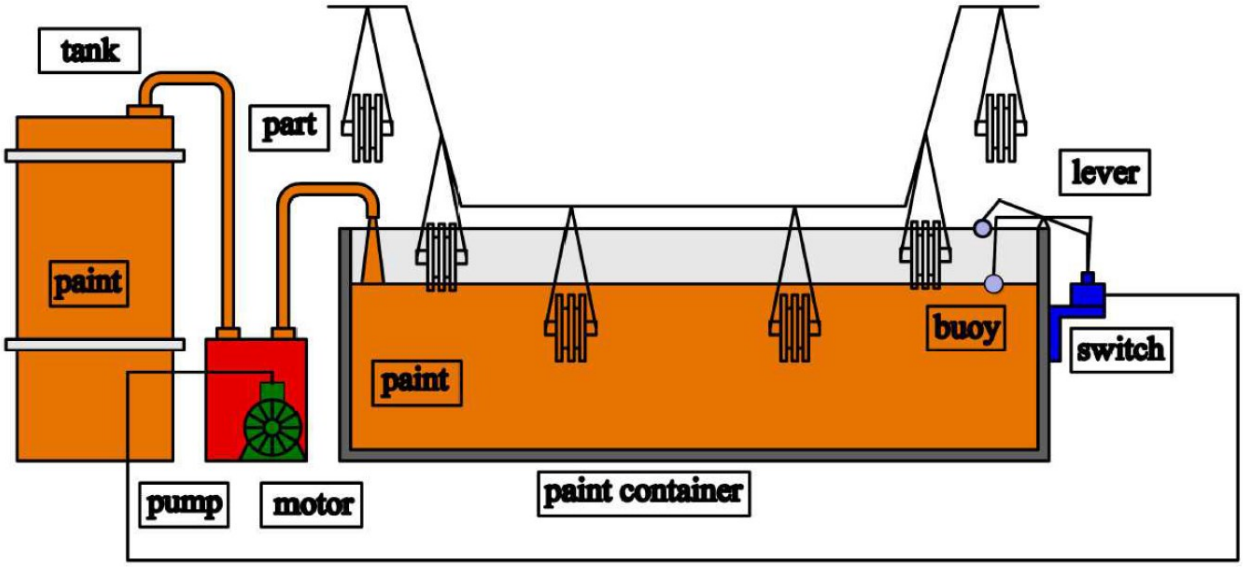

Figure 1. Sketch of the original painting system, in which overflowing is a problem.

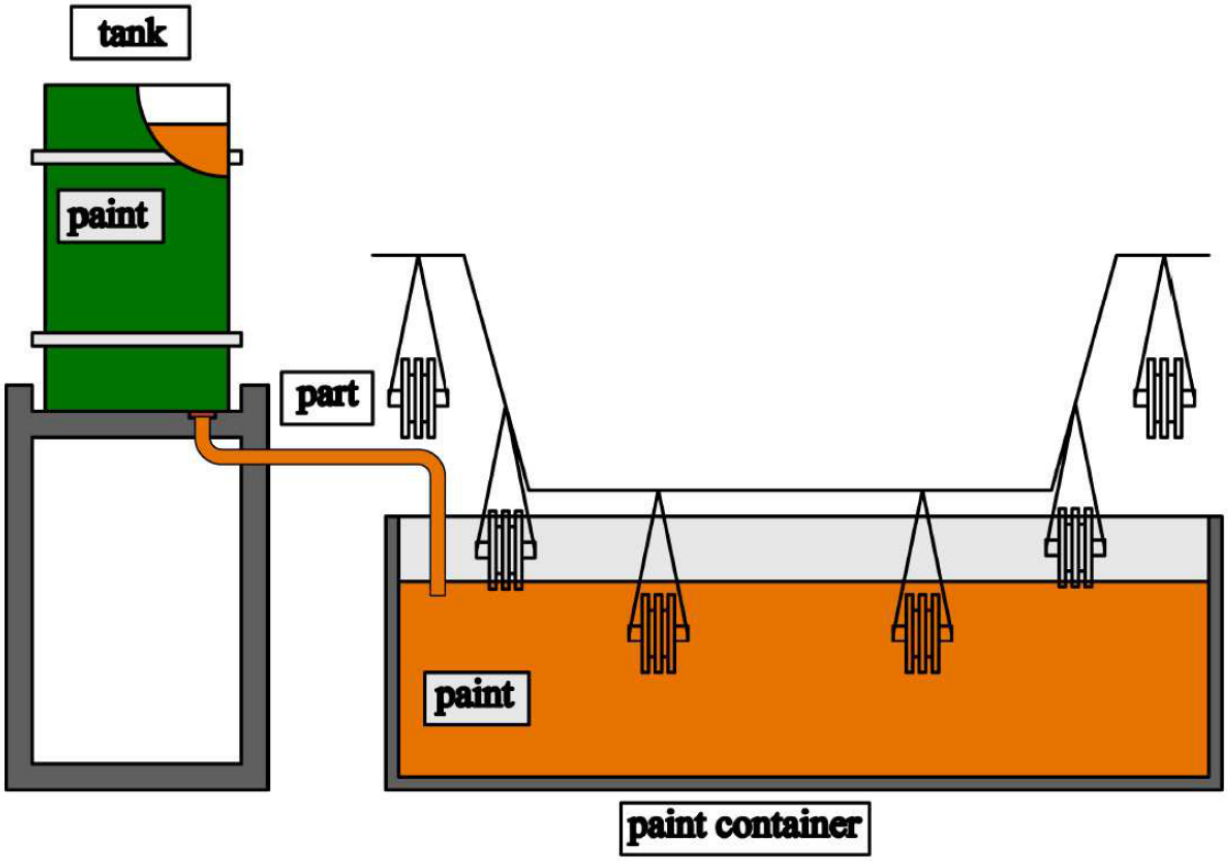

Figure 2. Sketch of the solution for the painting system that eliminates overflowing.

People who are not familiar with TRIZ can also use the concept of resources in their work. For example, in FlexSim simulation modeling software, the designer can use the situation of an incoming customer to trigger a count of the waiting time in the queue. The details of this process are given below (Task 1.1 - Build a 3D Model, 2022).

A simple queueing model is considered, in which customers arrive with an inter-arrival time that has an exponential distribution and a mean of 60 s. A service desk (such as in a barber shop) will first help those customers who have been waiting the longest, and the service time has a log normal 2 distribution with a location, scale and shape of 90, 3.1, and 0.5, respectively. However, customers who have waited more than 200 s will get frustrated and leave via the unhappy customers sink. Customers who have the chance of being served by the service desk and have not waited more than 200 s will be pulled from the waiting list and receive service at the service desk. There are two possible scenarios for a customer who is waiting in line: one is to be served at the service desk, and the other is to leave the system and become an unhappy customer. We are therefore unable to use an ordinary port connection between the waiting line and service desk, and a new set of logic operations needs to be established to fulfill the situation.

To create this functionality, we use a global list to filter and prioritize flows of items using sophisticated sets of criteria. We set up a flow item list named *WaitingCustomers*. For each item in the list, we set up a field which helps us keep track of the information on the items. One of these fields is called *WaitTime*, which tracks the length of time the item has been in the queue. But how should we update the value in *WaitTime*? Since FlexSim is a discrete simulation modeling package, the value of each flow item advances only when a new event occurs. The event that triggers the updating of *WaitTime* is an incoming customer to the queue. The 3D model and its parameter settings for each of the objects of this case study are described below.

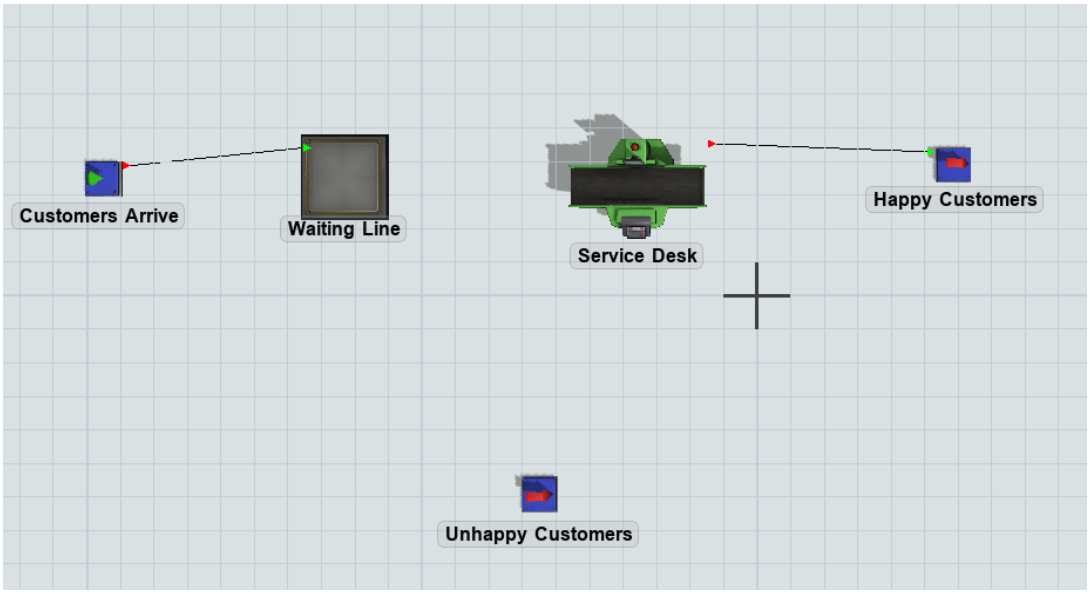

Figure 3. 3D model of a single service desk.

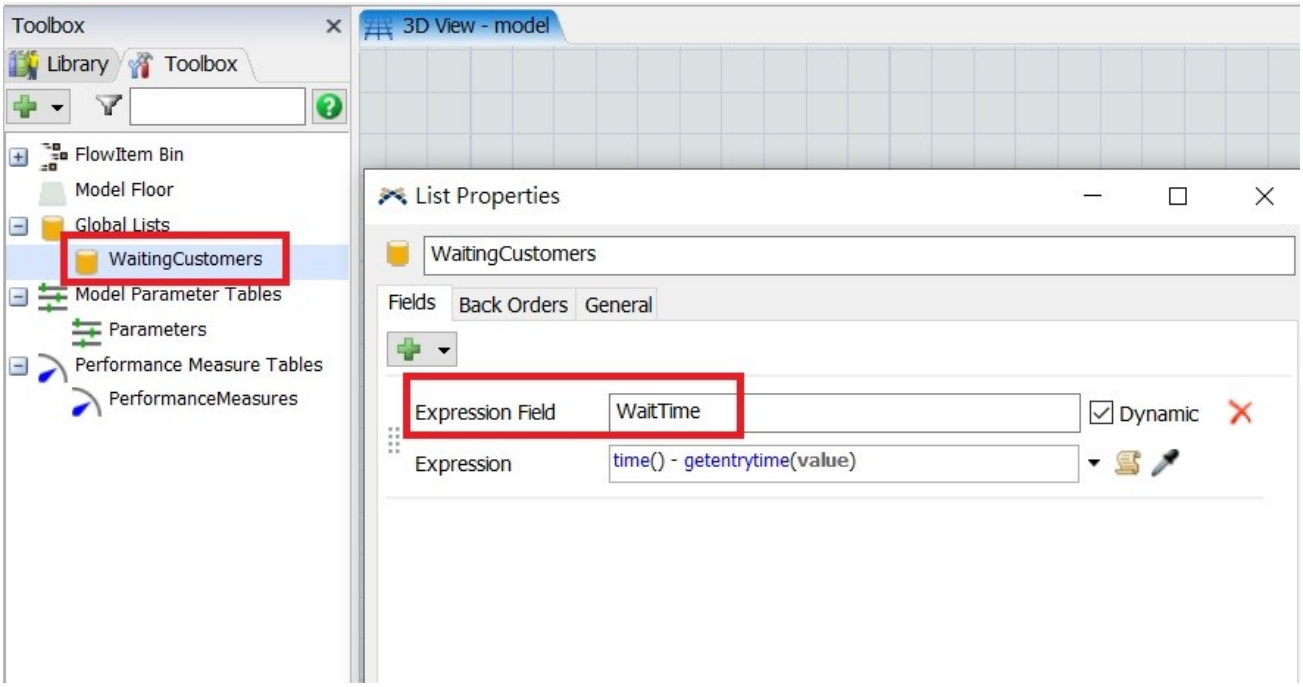

Figure 4. Setting up the global list *WaitingCustomers* and the *WaitTime* field.

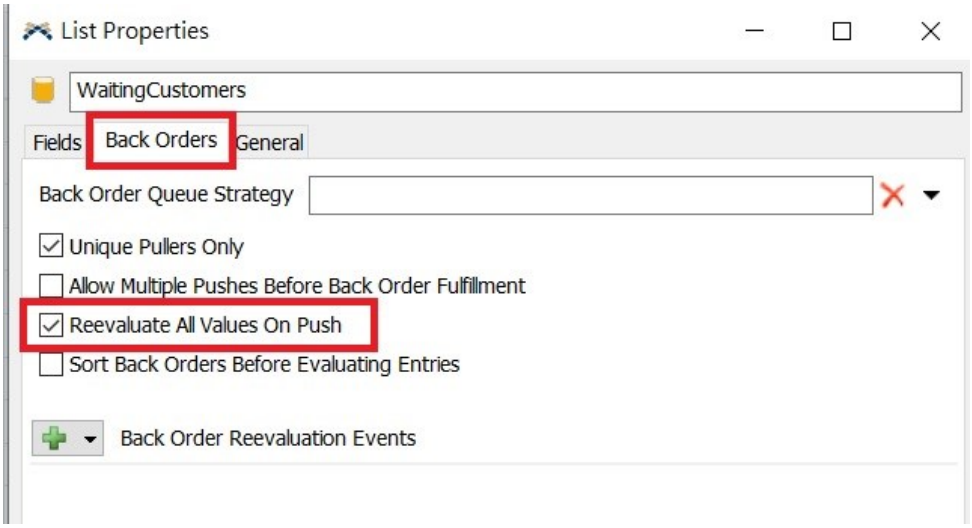

Figure 5. All of the values in *WaitTime* are reevaluated when a new customer joins the queue.

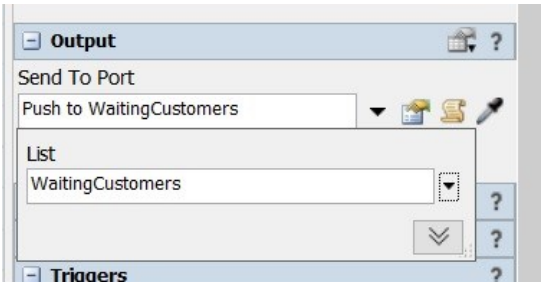

Figure 6. All of the customers in the queue are pushed to a list called *WaitingCustomers*.

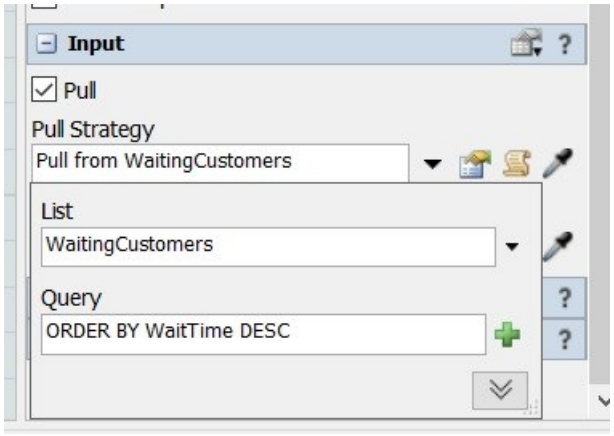

Figure 7. The customers are pulled from *WaitingCustomers* to the service desk.

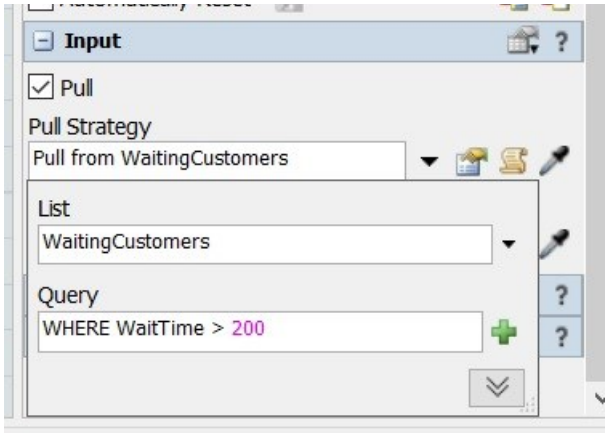

Figure 8. The customers are also pulled from *WaitingCustomers* to the unhappy customers sink.

Figure 3 shows the layout of our 3D model. Note that there are no port connections between the queue and the service desk, or between the queue and the unhappy customers sink; this is because a port connection ensures that the activity is executed, and since there are two possible scenarios following the queuing activity, no port correction should be made. But how does a customer proceed to the next station? We set up a global list called *WaitingCustomers* and push all the customers in the queue to the list, as shown in Figure 4. A field called *WaitTime* is used to keep track of the time spent by each customer in the queue. Under the tab entitled *Back Orders*, we check the box marked *Reevaluate All Values on Push* to update *WaitTime* when a new customer joins the queue, as shown in Figure 5.

Hence, when a customer is created from the source (*Customers Arrive*), it enters the queue and is pushed into a list entitled *WaitingCustomers*, as shown in Figure 6. When the service desk is free to serve a new customer, it pulls from the *WaitingCustomers* list the new customer who has waited the longest time, as indicated by the query field in the input section of the service desk. The value of the query field is set to *ORDER by WaitTime DESC* (meaning descending), indicating that the customer with the longest wait will always be served first, as shown in Figure 7.

Finally, the unhappy customers sink pulls any unhappy customer with a waiting time of more than 200 s. Note that the pull of the unhappy customers is activated when the new customers join the queue. At this moment, the wait times of the customers in the queue are reevaluated, and any with a wait time of more than 200 s will be pulled to the unhappy customers sink, as shown in Figure 8.

In summary, the 3D model uses the event of an incoming customer to the queue as a trigger to recalculate the waiting times of the customers in the queue, meaning that there is no need to set up a timer to keep track the waiting time of each customer in the queue. However, there is a problem with the conservation strategy in the discrete simulation, as the customers will stay in the queue for more than 200 s before they leave as unhappy customers. This is a typical example of a technical contradiction (Altschuller, 1984). This occurs when we try to improve one characteristic or parameter of a technical system and cause another to deteriorate. A contradiction matrix can be used to solve this problem.

In this research, we explore the possibility of using a timer to ensure the rule in which customers leave after 200 s in the waiting line, using a process flow model in FlexSim. We also adapt it to the parking patrol system used in certain areas of Taiwan. The similarities between the situation of a service desk and the parking patrol system give rise to the possibility of applying the solution for the service desk to the parking patrol system. The remainder of the paper is organized as follows: Section 2 presents a literature review, Section 3 introduces the process flow model and the experimental results, including data analysis and interpretation, and Section 4 contains the conclusion.

2. Literature review

The concept of resources was introduced in 1985 by Genrich Altshuller in the form of "substance-field resources," which formed a component of his Algorithm for Inventive Problem Solving (ARIZ). Later, this concept was expanded to include other types of resources such as functions, information, space, time, change, etc. (Zlotin and Zusman, 2005). Zlotin and Zusman (2005) also developed evolutionary resources, which help reveal hidden resources, and considered inventive resources including functional, fields, information, ideas, substances, space, time, and trends. The term 'resources of change' (or 'change resources', but not 'resources for change') means resources produced by a change to the system.

Bogatyrev and Bogatyreva (2011) proposed the seven stepping stones algorithm to break down the inventive challenge in a step-by-step way. In the fourth stage, resources come into play, and are used to create the conditions for the ideal final result. We systematically consider subtle changes to the parameters of all resources available within the system at hand, including even free environmental ones. A resource may be any object, attribute phenomenon, or process; in fact, it can be anything, as long as it is at the right time, in the right place, at the right dose, for the right consumers, and in the right mode. By applying a nine-window analysis of time and space to the system, we can obtain a full

view of the context of the system behavior, and avoid missing any opportunity to employ the existing resources. It is worth noting that Bogatyrev and Bogatyreva (2011) work with Bio-TRIZ, and most of their examples are inspired by biological evolution. Bio-TRIZ relies more on information resources than substance resources, which are more environmentally conservative.

However, even though Bio-TRIZ originated from the field of biology, it can be applied to other fields, such as space projects, social and behavioral challenges (Bogatyreva and Shillerov, 2015) and even logistical problems (Bogatyreva and Chao, 2013).

Mann (2007a, 2007b) proposed two ways of identifying resources within a system. The first is linked to the trend of evolution: from an evolutionary potential radar plot, we can perceive how much further a given system is able to evolve. In these plots, every bit of unused evolutionary potential represents a resource. The second approach is to provide a trigger list of resources that other problem solvers in other fields have at some time successfully harnessed as resources.

A resource can be regarded as a function carrier, and can be used to perform a function on a receiving object. With proper trimming rules, this resource can be identified. Weaver (2009) proposed six trimming rules that are very helpful for function analysis. In a function analysis, the problem is represented as a function layout, where objects in the system interact with one another based on the functional relationship. Using the six trimming rules, we can identify a hidden object in the function analysis with its hidden function so that the function can be trimmed or replaced by another existing component in the system or supersystem. Sheu and Hou (2015) expanded further on the six trimming rules and developed a two-loop, depth-first, recursive trimming process to maximize the trimming effect. An industrial case of a slit-valve failure problem was tackled with the algorithm, and breakthrough results were presented.

None of the above researchers discussed the side effects of a using free resource, especially in the field of software and simulation modeling. Since information and knowledge are some of the key competitive weapons of our time, the companies that have the best information or wield it most effectively will win in the competitive market (Stewart, 1997; Schumacher, 1999). We feel that it is important to discuss the cost of misuse of misleading information due to the use of a free resource to trigger the measurement of waiting time in the queue. We will also investigate its ramifications in terms of the issuing of parking tickets by a patrolling enforcement officer within cities in Taiwan.

We start with an introduction to the importance of simulation modeling. One reason for this is that the ordinary equations used in queuing theory cannot handle the complexity of a modern logistical system. In order to gain insights into the dynamic behavior of a complex system, we need to use simulation modeling. Here, ‘dynamic’ means the discrete flows of products, people, data, paper, or information through a system. Examples include the flow of people in a railway station (Kuzmin, Baginova and Ageikin, 2022), ladles flowing through a steel plant (Wu, Xu, Song and Li, 2019), or a

car frame going through the interior assembly line section in an automobile production plant (Wang and Chen, 2016).

For dynamic flow systems, which are characterized by complexity and uncertainty, FlexSim can be a powerful tool for gaining insight and knowledge about the system. It is only when the relationships between a system's components are understood that the system can be improved.

The waiting time of a flow item (such as a customer or part) in a system is one of the seven source of waste in lean production (Ohno, 1988). To reduce the waiting time, we first need to measure the waiting time, which occurs when the flow item stays static and no value-added operations are applied to it. For example, patients wait in a waiting room before being seen by a physician, and customers wait in a barber shop before being served by the barber.

Beaverstock, Greenwood and Nordgren (2017) stated that waiting times in a process can be grouped into three categories: customer waiting time, product waiting time, and machine waiting time. The problem with these waiting times is that they result in a tug-of-war that pits customers, products, and machines against each other. We need to know what these waiting times are and weigh the cost of each.

This three-way tug-of-war arises as follows. For example, a machine may be too highly loaded, which will cause a large queue to build up in front of the machine, and may also starve processes downstream. Thus, the product waiting cost increases and deliveries to the customer may fall behind, increasing the cost in terms of the customer waiting time. In this case, a reduction in the machine waiting time will cause an increase in both the product waiting time and the customer waiting time.

Queues start the moment the supply of products or customers is greater than the processing capacity. Another factor that can influence the length of the queue is the variation in the processing time. An example given by Beaverstock, Greenwood and Nordgren (2017) is used to demonstrate how the waiting time can be influenced by the processing time, as follows.

Suppose we have an M/G/1 queuing system, where the customers arrive with the Poisson process, the service times have a general distribution, and there is a single server. The average waiting time $(\bar{W}_t)$ is:

$$\bar{W}_t = 0.5(1 + {c_v}^2)\left(\frac{\rho}{1-\rho}\right)\bar{P}_t, \qquad (1)$$

where c_v is the coefficient of variation of the service time, and is defined as the ratio of the standard deviation to the mean; ρ is the utilization of the server, and is defined as the ratio of the arrival rate to the service rate; and $\bar{P}_t$ is the average service time. Note that in the original formula given by Beaverstock, Greenwood and Nordgren (2017) c_v is used instead of ${c_v}^2$, which we believe is a typo; the correctness can easily be checked using the Pollaczek–Khinchine formula in Wikipedia

(Pollaczek–Khinchine formula, 2021). Furthermore, if λ is the arrival rate of the Poisson process, μ the service rate of the server, and σ the standard deviation of the service time, we can express Equation (1) as:

$$\bar{W}_t = 0.5(1 + (\sigma\mu)^2)\left(\frac{\lambda/\mu}{1-\lambda/\mu}\right)\left(\frac{1}{\mu}\right). \qquad (2)$$

Suppose that the processing time for a production step is 5 min, and the utilization of the machine is 90%. We also assume that the service times have an exponential distribution, giving an M/M/1 model. Here, the value of λ is 10.8 customers/hour, μ is 12 customers/hour, and σ is $1/\mu$ = 1/12 hours/customer. Thus, Equation (2) becomes:

$$\bar{W}_t = 0.5\left(1 + \left(\frac{1}{12} * 12\right)^2\right)\left(\frac{\frac{10.8}{12}}{1-\frac{10.8}{12}}\right)\left(\frac{1}{12}\right)$$

$$= \frac{9}{12} = \frac{3}{4} \text{ h} = 45 \text{ min.} \qquad (3)$$

If we could optimize the working process and reduce the time by 10% (5 min * 10% = 30 s), would the average waiting time be significantly reduced? At first glance, it does not appear that the waiting time would be reduced by much; however, plugging these figures into Equation (2) gives:

$$\bar{W}_t = 0.5\left(1 + \left(\frac{1}{12} * 12\right)^2\right)\left(\frac{\frac{10.8}{\left(\frac{12}{0.9}\right)}}{1-\frac{10.8}{\left(\frac{12}{0.9}\right)}}\right)\left(\frac{1}{\frac{12}{0.9}}\right)$$

$$= 0.5(1+1)\left(\frac{0.81}{1-0.81}\right)\left(\frac{1}{12/0.9}\right) = \frac{0.243}{0.76} \text{ h} = 19.18 \text{ min.} \qquad (4)$$

With this value, the waiting time is 19.18 min. The total throughput decreases from 50 min to 23.68 min, a reduction of approximately 50%. This seemingly small change in processing time results in a significant reduction in the waiting time.

Although using mathematical formulae to calculate waiting times is easy for simple M/G/1 systems, more complex systems are commonplace in today's manufacturing and logistics environment. In this case, mathematical analysis and spreadsheet calculations fall far short of what is needed to measure and understand the behavior of complex stochastic processing and logistic systems. Understanding and managing the competing costs of waiting is critical to the profits of every company, yet very few managers understand these relationships and the effect that waiting has on costs and customer satisfaction, and even fewer know how to measure these effects to manage the process.

Another issue we want to address is the modeling methods used in FlexSim. Suppose that we are interested in knowing the average waiting time in a simple queue with one processor, similar to an M/M/1 system. To make the system more realistic, we add a limit to the waiting time that the customer will tolerate: if the customer waits more than 200 s, he/she will become frustrated and will leave the system. This system is shown in Figure 3. There is an important issue here that is related to measuring the waiting time, as the 3D model uses an incoming customer to activate the updating of the waiting time of the remaining customers in the queue. Although the use of this measure is very smart, because it avoids the need to apply an additional timer, it means that there will be a measurement error in the waiting time of those frustrated customers who leave the system without being served. As we will show later, the actual waiting time of the frustrated customers is more than 200 s; indeed, in some cases the waiting time can reach 398.83 s. We know from Maister (1984) that extra waiting time causes customer resentment. The statement from the Federal Express advertisement slogan is true: "Waiting is frustrating, demoralizing, agonizing, aggravating, annoying, time consuming and incredibly expensive." Knowing the accurate waiting time of a frustrated customer is very important from a managerial perspective, and misleading information on waiting times can cause great problems in terms of retaining potential customers.

Accurate timing for a customer entering the system is also an issue in the case of parking patrols in cities. Some cities use parking meters to measure the car parking time, as this is an effective way for the local city to collect parking fees from users. However, not all cities use parking meters, due to the extra expense involved in installing and maintaining them. Instead, they hire an officer to patrol the streets and place a ticket on the windshield of each parked car, thus keeping track of the parking time for that car. If you consider the cases of the parking ticket and the waiting time in the 3D model, you will see there is a point of commonality between them, which is the activating mechanism used to measure the waiting time: one uses a patrolling officer, while the other uses a new, incoming customer. If we can get an accurate record of the waiting time for the 3D model, the user can take measures to reduce the service time at the service desk in order to reduce the numbers of frustrated customers, or to take some other managerial action to alleviate the discomfort of the waiting experience. In the case of the patrolling officers, it will increase the income to City Hall. Thus, solving this problem will have some ripple effects on the fees collected by the patrolling service.

Kim, Song and Kim (2012) introduced a modified version of the parking enforcement system which used smartphones to allow ordinary citizens to report parking violators to parking enforcement officers. The procedure in this system is for a citizen to take a picture of a vehicle in violation, send the violation report virtually, and finally report whether the car remains in the same location after five minutes have passed. The smartphone parking enforcement solution utilizes GPS in order to input the time and location data. In this kind of system, enforcement authorities including citizens do not have to input the time or location information manually, and simply by taking a picture with a smartphone, the violating car's information can be retrieved from the central database. With these features,

everyone can be a warden. This system could efficiently reduce the inconvenience caused by parking violations.

We can easily transfer this concept to the problem of a parking ticket given by a patrolling officer. The registered citizen can take a picture of a parked car if he/she notices that there is no parking ticket on the windshield. Then the central database will send a signal to the dispatcher (which could be a human or a computer system) to notify the closest patrolling officer about that parked car.

A second approach can simplify the previous solution further. The city patrolling station could use a LINE app group to replace the function of the central database. Any registered citizen can join the group, and when he/she sees an unattended car in a parking space, can take a picture and upload it to the group. The dispatcher will immediately notify the nearest patrolling officer of the unattended car to give it a ticket on the windshield.

In the following section, we will present a process flow model that is a counterpart to the 3D model. A histogram of the waiting times in both systems will be compared to show the superiority of the new process flow model.

3. Process flow model and experimental results

Unlike an object-based 3D model, a process flow uses event activity to represent a modeling system. An activity is similar to a chunk of logic or a logical operation in a simulation model. One advantage of using a process flow tool is the relative ease of creation of a custom model logic in this tool. The layout of the process flow corresponding to the 3D model is given below (Task 1.3 - Build a Process Flow Model, 2022). Figure 9 shows that when a token is created in the inter-arrival source, it will try to get a resource before it proceeds to perform the processing work in the service desk. For this reason, the *Acquire: Get Service* activity is connected to the *Resource: Service Desk* activity. There are two connectors from the *Acquire: Get Service* activity: one is connector 1 to the *Delay: Service Time* activity, and the other is connector 2 to *Sink: Unhappy Customers*. By default, the *Acquire: Get Service* activity will connect via connector 1 to the *Delay: Service Time* activity, meaning that after acquiring the resource, the token will immediately enter the service desk and receive the service typified by the *Delay: Service Time*. However, for those waiting in the *Acquire: Get Service* activity, if their waiting time is more than 200 s, they will be sent to *Sink: Unhappy Customers* via connector 2, as shown in Figure 10. In this way, the process flow fulfills the requirements for system modeling. We set up the inter-arrival source with an exponential distribution with a mean of 60 s and the *Delay: Service Time* with a log normal 2 distribution with location, scale, and shape of 90, 3.1, and 0.5 respectively. We ran the program for 12 h, and obtained the results for the process flow and a histogram of the waiting time as shown in Figures 11 and 12. In Figure 11, there is one token in the *Delay: Service Time* activity, meaning that the token has reached the limit on the waiting time but has not

been pushed out of the system. Thus, there should be 302+453+1=756 values for the waiting time, as shown in Figure 12. We can easily add up the numbers in each bin to get a total of 756.

From the dashboard in Figure 13, we see that the numbers of unhappy and happy customers are 302 and 453, respectively. The 302 unhappy customers have all waited for 200 s in the queue, and constitute the majority of the last block of the histogram to the right of Figure 12. The values for the minimum, maximum, average, and standard deviation in the waiting time for both the unhappy and happy customers are 0, 200, 156.37 and 54.69 s, respectively. If we consider only the waiting times of the 453 happy customers, the values of the minimum, maximum, average, and standard deviation in the waiting time are 0, 199.99, 127.36, and 53.59 s, respectively.

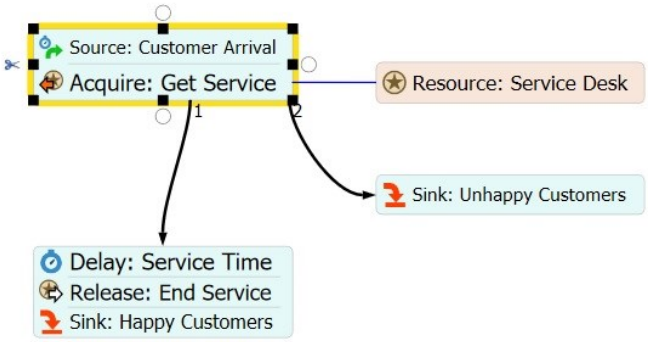

Figure 9. Process flow model.

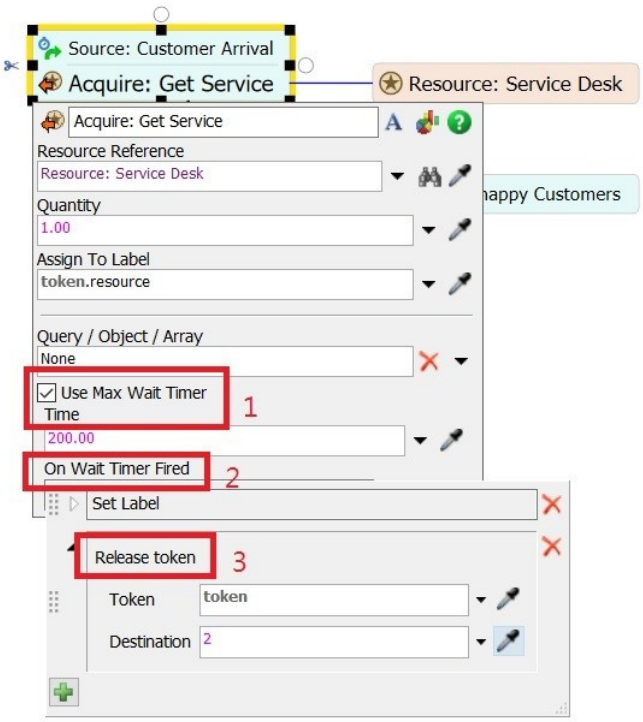

Figure 10. Parameter value settings for the process flow model.

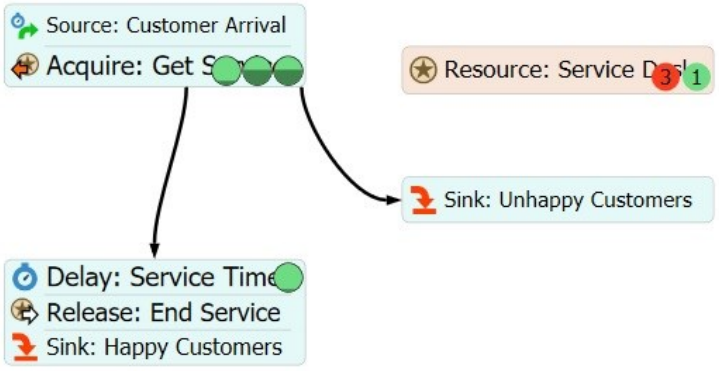

Figure 11. Final snapshot after running the process flow for 12 h.

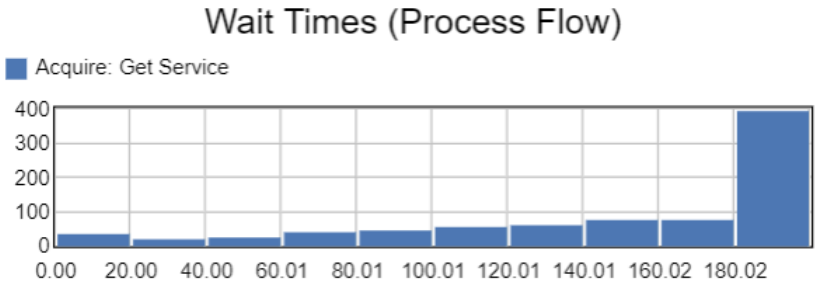

Figure 12. Histogram of the waiting times in the queue of the process flow.

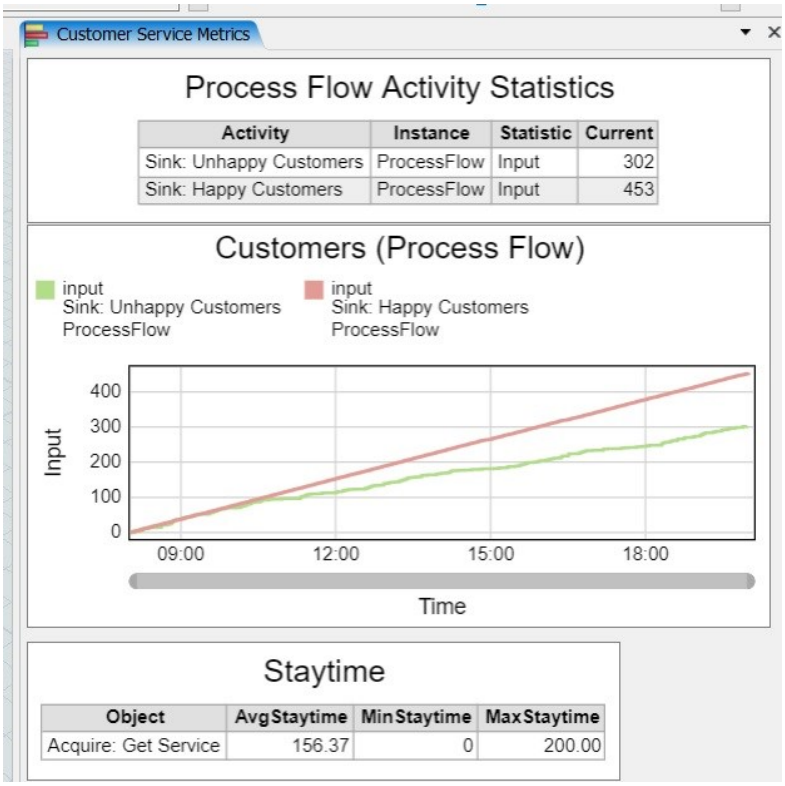

Figure 13. Dashboard for the process flow.

We also used the 3D model to create a histogram of the waiting times, and the results are shown in Figure 14. There were 278 and 455 unhappy and happy customers, respectively. Note that these numbers are different from their counterparts (302 and 453) in the process flow due to the fact that different random seeds were used, even though the distributions were the same. If we separate the data in Figure 14 into two groups representing unhappy and happy customers, we get the two separate histograms in Figures 15 and 16. Figure 17 shows that within these 278 waiting times for the unhappy customers, the minimum, maximum, average, and standard deviation in the waiting times are 200.10, 398.83, 237.88, and 35.40 s, respectively. For the 455 waiting times for the happy customers, the minimum, maximum, average, and standard deviation in the waiting times are 0, 354.84, 162.38, and 70.88 s, respectively.

Two points are worth noting here. Firstly, the waiting time for happy customers may be more than 200 s. This may initially sound strange, since if the waiting time is more than 200 s, the corresponding customers should go to the unhappy customers sink; however, a moment's thought reveals that this is possible due to the fact that the simulation model is based on discrete events. When a customer has waited more than 200 s, it will not be pulled into the unhappy customers sink unless a new customer has entered the queue, which triggers the pulling action from the unhappy customers sink. If during this time, the service desk happens to be available, it will pull the customer with the longest wait, which may be more than 200 s, into the service desk. Thus, it is possible that the waiting time of a happy customer can be more than 200 s. Secondly, the average waiting time of the unhappy customers is 237.88 s. In contrast to the results from the process model, in which the waiting time of an unhappy customer is always 200 s, the modeling results from the 3D model surely mislead us.

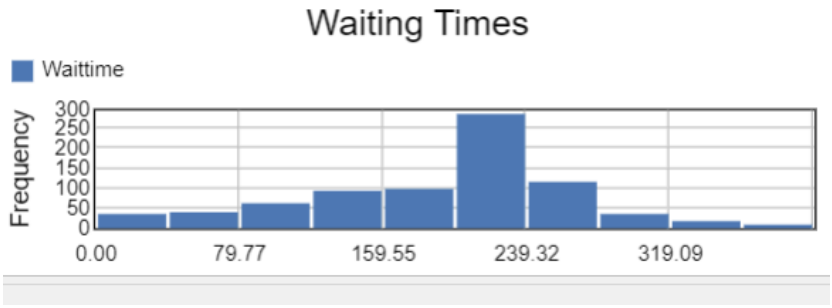

Figure 14. Histogram of waiting times from the 3D model.

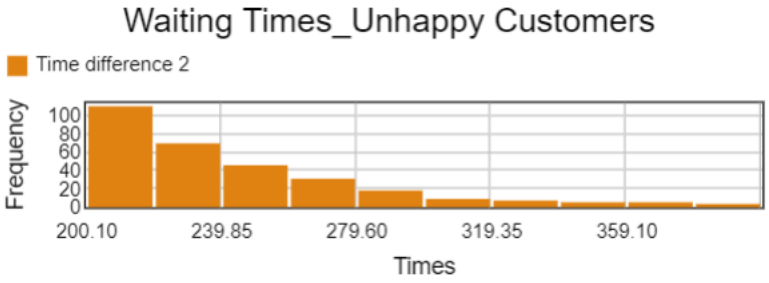

Figure 15. Histogram of waiting times for unhappy customers from the 3D model.

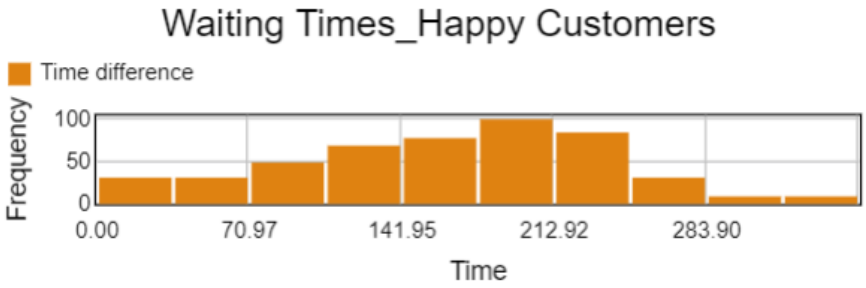

Figure 16. Histogram of waiting times for happy customers from the 3D model.

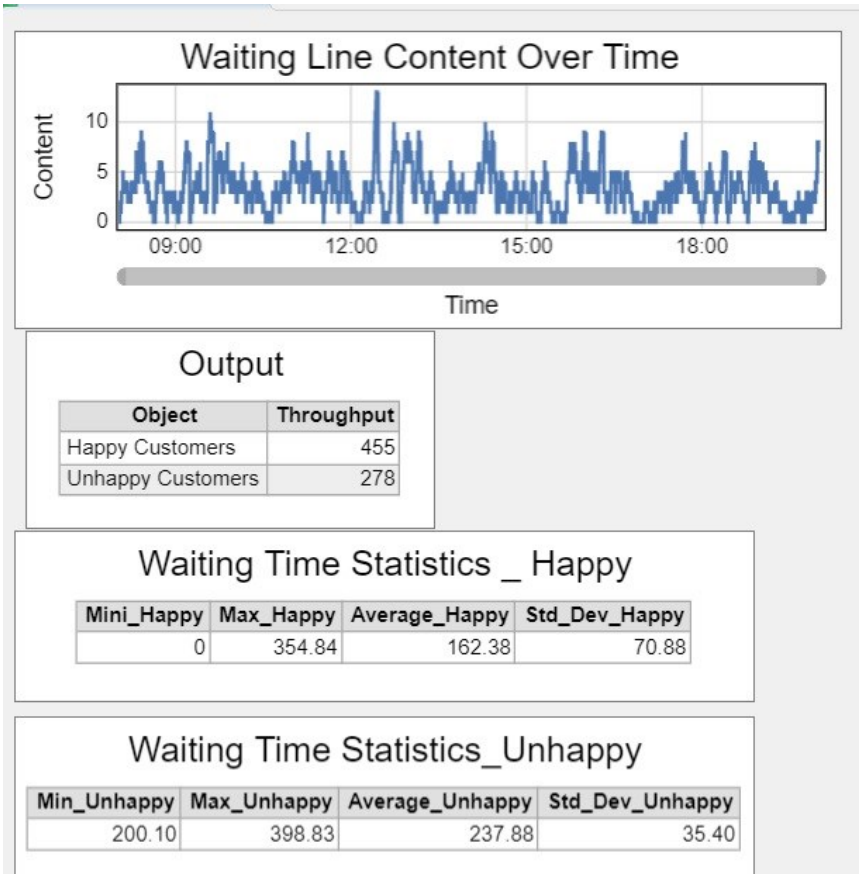

Figure 17. Dashboard of 3D model.

Here, we discuss these results from the perspective of TRIZ. As mentioned previously, the use of hidden resources is a clever way to solve a technical contradiction. In the simulation modeling problem, we needed to use a timer to keep track of the waiting time of each customer in the queue, but using a timer imposes a load on the system and slows down the running speed. Thus, the modeler uses a hidden resource, i.e., the event of an incoming customer into the queue, to update the waiting times. In this way, the need for a timer is avoided, and the problem is solved. At this point, we might say an ideal solution has been reached in TRIZ terms; however, we have not considered the ripple effects of this solution, or the correctness of the waiting times. Managers may want to know the correct values of the waiting times so that they can apply proper measures to improve the quality of the service system, but

the use of this method jeopardizes the measurement of waiting time. Here, we have a new insight: when we solve a TRIZ problem, sometimes we are only solving the problem based on a functional analysis, and a related characteristic may be neglected. In our case, this neglected characteristic is the issue of measurement.

Secondly, there are further ramifications here. The concept of using the event of an incoming customer as a trigger is similar to the system used by patrolling officers for parked cars in the street. The current practice of issuing a ticket to an unattended car parked in the street involves a similar problem to the measurement error of the waiting time. Thus, a free timer must be found to solve the problem. We suggested above that a LINE app group could be used for the patrolling problem. A registered citizen can take a picture of an unattended car in the street, and the appropriate patrolling officer will be called to the parked car to give it a ticket. Of course, this free timer solution is close to (but not identical to) the ideal final solution; however, it fits the spirit of TRIZ problem solving, in which we try to solve a technical contradiction and get a result that is close to the ideal final result.

4. Conclusions

Resources are very powerful when used to create the conditions for the ideal final result. One important strategy is the use of change resources to adjust the parameters of the resource so that it fits the conditions for the ideal final result. A change resource is a hidden one, a resource that exists but has not yet been noticed in the context of the problem. Most examples of resources involve the substitution of the function of the needed object with another object that is already in the system.

Although many researchers have proposed architectures for implementing resources, none of them have focused on the possible side effects of the measurement of a critical value, which in this case is the waiting time. It is possible that without proper consideration of the resource, misleading figures could jeopardize a management decision. We give the example of waiting times in a queue in a simple simulation model to demonstrate this scenario. We believe this example sheds some light on the importance of choosing the proper resource to fulfill the system requirements.

The simulation of the system starts by generating incoming customers with inter-arrival times that are exponentially distributed with a mean of 60 s. A customer entering the queue waits to be served by the service desk. The service time of the server is a log normal 2 distribution with values for the location, scale, and shape of 90, 3.1, and 0.5, respectively. There is a second possible destination for the customers in the queue: if they wait for more than 200 s, they will leave the system as a frustrated customer. There are some managerial issues here that need to be addressed. Firstly, the owner of system needs to know the average waiting times for the two categories (happy and unhappy customers). Theoretically, the waiting time of an unhappy customer is always 200 s, and for the happy customers this is always less than 200 s. However, this only holds true if a timer is used for each incoming customer to keep track of the waiting times. Timers take up space in the memory and slow down the

running speed of the simulation model, and hence a hidden resource is identified to replace the timer, which is the event of a customer entering the queue. Since the simulation software used here is FlexSim, a discrete event-based simulation, the use of a free resource in the form of an event of an incoming customer to trigger the updating of the waiting times is very clever, as it reduces the number of objects and simplifies the model. From the perspective of TRIZ, it is very successful in terms of Trimming Rule C, which states that the function carriers can be trimmed if another existing component in the system or super system can perform the useful function of the current function carrier (Sheu and Hor, 2015). However, it is only effective in terms of function, and we need to consider the ripple effect on the measurement of the waiting time in the queue.

From a 12 h run of the model, two startling results were found. Firstly, rather than a fixed waiting time of 200 s, the average, standard deviation, and maximum waiting times for unhappy customer were 237.88, 35.40, and 398.83 s, respectively. Secondly, despite the waiting time for happy customers being limited to less than 200 s, there were 152 happy customers whose waiting time was more than 200 s, representing 152/455=33% of them. The average, standard deviation, and maximum waiting times for happy customers were 162.38, 70.88, and 354.84 s, respectively.

When we used a process flow to replace the 3D model, the simulation results were similar to those expected. There were 302 unhappy customers, each of which spent 200 s in the queue. Moreover, there were 453 happy customers, all with waiting times of less than 200 s. The average, standard deviation, and maximum waiting times for happy customers were 127.35, 53.59, and 199.99 s, respectively.

From a comparison of the statistics for the 3D model and the process flow, we can easily see that for both happy and unhappy customers, the results were quite different. For the unhappy customers, the average waiting time in the 3D model was 237.88 s, whereas for the process flow this was 200 s. For happy customers, the average waiting time in the 3D model was 162.38 s, whereas for the process flow it was 127.35 s. The 3D model gives a significant increase (118.9%) in the average waiting time for the unhappy customers, and this is even larger (127.5%) for the happy customers.

Note that waiting is very annoying and demoralizing for customers, and causes feelings of resentment. Careful treatment of the waiting problem is therefore crucial to the success of a service industry. Accurate measurement of waiting times is an important weapon that can be wielded to ensure the prosperity of a company. Although using the concept of resources could reduce the usage of an extra object in the system, further consideration is essential for the subsequent measurement of waiting time.

Finally, the concept of using incoming customers as a trigger to update the waiting times can have ramifications for the issuing of tickets to cars parked in the street. Currently, the majority of parking fee collection is done via patrolling officers, and a visit by a patrolling officer is similar to the use of an incoming customer to the queue to trigger the waiting time. Based on research by Kim, Song and

Kim (2012), we suggest the use of the LINE app as a data center where a registered citizen can take a picture of an unattended car in the street and upload the picture to the group. A dispatcher can then assign a patrolling officer to the car to give it a parking ticket.

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A Method for Product Hidden Flow Problem Mining Based on Expected Failure Analysis and Petri Nets

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Abstract

The realization of product function is accompanied by the mutual transfer and transformation process of internal material, energy and information flow. In this process, changes in flow attributes and types can negatively affect other flows, resulting in flow problems, some of which are hidden flow problems that are difficult to identify. The existing flow problem analysis methods, especially the limitations of the hidden flow problem analysis method, so this paper puts forward the product hidden flow problem mining and solving methods. Firstly, according to the total function of the product, the functional decomposition of the product is carried out, and the flow is introduced to build the functional structure chart of the system. The analysis of the functional structure adopts the method of Anticipatory Failure Determination(AFD) to predict and judge the functional failure area in the functional structure from the angle of reverse thinking. Then, the corresponding function-behavior mapping rules are proposed. According to the rules, the functional structure is transformed into Petri net behavior model. Based on the analysis of the accessibility of behavior model, the behavior failure area is judged, and the hidden flow problem in the product is preliminary determined by mapping. Then, based on the flow involved in the failure area, combined with the analysis of the flow attributes, the existing hidden flow problem is confirmed. Finally, the solution strategy based on the law of flow evolution was adopted to solve the hidden flow problem, and the multi-functional nursing bed was taken as an example to verify the effectiveness of the proposed method, and the innovative design scheme of the product was obtained.

Keywords: Hidden flow problem, Petri net, AFD, Laws of flow evolution

The realization of product function is accompanied by the mutual transfer and transformation process of internal material, energy and information flows. In this process, the change of flow attributes and types will cause other flows to be negatively affected, resulting in flow problems. The existing flow problem analysis methods, especially for the hidden flow problem analysis has limitations, so this paper puts forward the product hidden flow problem mining and solving method. Firstly, the total function diagram and function decomposition tree of the product are introduced to build the system function structure diagram. Anticipatory Failure Determination (AFD) of the functional structure can predict the functional failure area and hidden flow problems. Then, according to certain mapping rules, it is transformed into the behavior model of Petri net. Based on the accessibility analysis of the behavior model, the behavior failure area is judged, and the hidden flow problems in the product are determined by mapping. A flow problem solving strategy based on flow evolution law is adopted to solve the flow problem. In this paper, the process model of product hidden flow problem mining and solving was established. Finally, the multi-functional nursing bed was taken as an example to verify the effectiveness of the method and obtain the innovative design of the product.

Product function is complex. Product function tends to be diverse, the structure is gradually complex. Internal data and structural coupling are also becoming more and more diverse. The realization of the function of product system is accompanied by the transfer and change of material flow, energy flow and information flow. Complex and diverse system structures are more easily affected by the interaction between internal flow and flow, which makes flow problems more prominent and leads to functional defects or failures of the system.

Flow can be seen everywhere in our daily life. For example, the vehicles running on the highway are material flow, the thermal energy generated by thermal power generation is energy flow, and the information flow transmitted by people who are thousands of miles apart communicate with each other through mobile phones. There are many problems in the form of flow, such as poor mobile phone reception in elevators, crowded crowds during the Spring Festival, insufficient power supply in some remote areas, and underground landslides.

As for the definition of a problem, many scholars have different opinions to varying degrees. Based on the different definitions of a problem by different scholars, the common point is to define a problem as the gap between "expected state" and "current state". Junichi Sato divided problems into generative problems, hypothetical problems and exploratory problems. Generative problems refer to problems that have occurred or can be determined in advance. Exploratory problems refer to problems that do not appear at the present stage, but it will lead to problems if the target value or level is increased; What-if problem refers to a problem that does not occur in the current system, but is caused by setting an unprecedented and new target value. Based on Junichi Sato's definition of flow problems, flow problems are divided into dominant flow problems and hidden flow problems, and inevitable flow problems are predetermined to be dominant flow problems. Flow problems belonging to hypothetical and exploratory problems belong to implicit flow problems, that is, new system goals are raised or set, resulting in the gap between the existing level of the system flow problems are defined as implicit flow problems.

The analysis of convection started from the study of material flow abroad in 1969 . After

that, people gradually began to study material flow, energy flow, information flow and other multi-flow problems. TRIZ theory was first proposed by Simon Litvin and Alex Lyubomirskiy, masters of TRIZ in GEN3. At present, scholars at home and abroad mainly focus on defect, network, model and collaboration.

In terms of internal flow defects of products, Sun Yongwei believes that flow analysis is to make an in-depth analysis of material flow, energy flow or information flow in the product system, in order to determine some possible shortcomings of these flows, such as flow bottleneck, excessive flow, flow conversion and harmful effects of flow. Wu Daoxiang made an in-depth study of hot forging forming of 7050 aluminum alloy aviation forgings. Numerical and experimental methods were used to describe the problem of flow defects, and the mechanism of flow defects and its influencing factors were analyzed.

In terms of the analysis of the internal flow network of products, Wang Juan established the multi-flow problem network and transformed the multi-flow problem network into a conflict network. Finally, TRIZ and ARIZ tools were used to solve the problem. However, the analysis process is subject to subjective factors. Sun Jianguang proposed a problem flow network transformation process model for interdisciplinary problems, and used this model to effectively solve the heating problem of high-current-charge gun and cable.

In terms of flow model analysis of products, Wang Xuerui constructed a multi-flow problem analysis process model for complex products based on multi-flow problem analysis, analyzed and screened multi-flow problems in complex products, determined the main multi-flow problems, proposed optimization strategies for multi-flow problems, and supplemented the content of flow analysis. Wu Dongrun studied the blades of multistage axial flow compressors and established the flow analysis model and prediction model, which improved the aerodynamic design of high-pressure compressors.

In terms of product flow synergy, Long Yan explained the synergy mechanism of material, energy and information flow in the large-scale system, and proposed the flow mechanism based on interdisciplinary studies. Hu Zhengbiao studied the influence mechanism and synergy law between material flow and energy flow, and specifically proposed the synergy characterization method between flows and the production plan optimized by algorithm. Based on the synergetics theory, Li Gang studied the information physical energy system and established the CPES multi-flow synergetics and multi-level optimization analysis model of "material flow-energy flow-information flow-capital flow".

At present, scholars at home and abroad have studied the flow problems of various products and systems from different aspects and angles, and put forward different analysis models and solving strategies. However, the analysis process is easily affected by subjective factors, and the analysis results may not be comprehensive and the analysis methods are not perfect. For flow problem analysis, subjective factors often accounts for more than major, the product of internal material flow, energy flow and information flow analysis of the combination of theoretical research is few, objective analysis tool of internal flows of dominant, recessive flow is less, so the need for product oriented recessive flow problem analysis and solving. To solve these problems, this article first from the analysis on product features, first of all, build the total product function tree diagram and the function, establish the function of product structure, according to the mapping rules for the behavior of Petri net model, the function structure of the excavated hidden within the expected failure analysis

flow problem, accessibility analysis model based on behavior, behavior failure area is determined, Finally, the flow problem is solved by flow problem solving strategy based on flow evolution law.

1 Functional failure prediction based on expected failure analysis

1.1 Anticipatory Failure Determination

Anticipatory Failure Determination (AFD)was proposed by Zlotin et al when facing the failure problem from the perspective of reverse thinking. Its core idea is to reverse the ideal state by reverse thinking and find out "all" possible failure modes in the system, so as to identify the occasions where failure may occur but has not yet occurred. AFD is divided into two types, AFD-1 and AFD-2. AFD-1 is called failure analysis and is used where a failure has occurred. AFD-2 is called failure prediction, which is used to identify the occasions where failure may occur but has not yet occurred. In this paper, AFD-2 is used as an analysis tool to predict the functional failure area and mine hidden flow problems.

1.2 Function and functional structure

Functionality is implemented with flow participation.Functionality always presupposes the existence of streams. Functional structure set up is based on functional decomposition, after decomposition to comprehensive and clear understanding of the product, and analyze customer needs, clear to design the product function, expresses the relationship between input, output, product, input, output, is composed of energy flow, material flow, information flow, according to user requirements, the product function decomposition company always have energy flow, material flow and information flow, And easy to implement sub-function set. The sub-functions are decomposed into functional elements, and the model composed of functional elements, input and output streams is the functional structure.

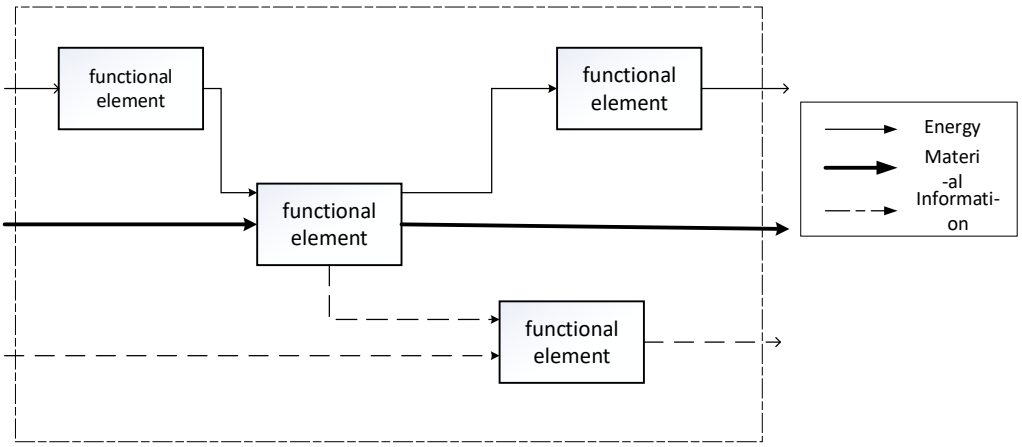

Figure 1. General functional structure

1.3 Function failure prediction based on AFD-2

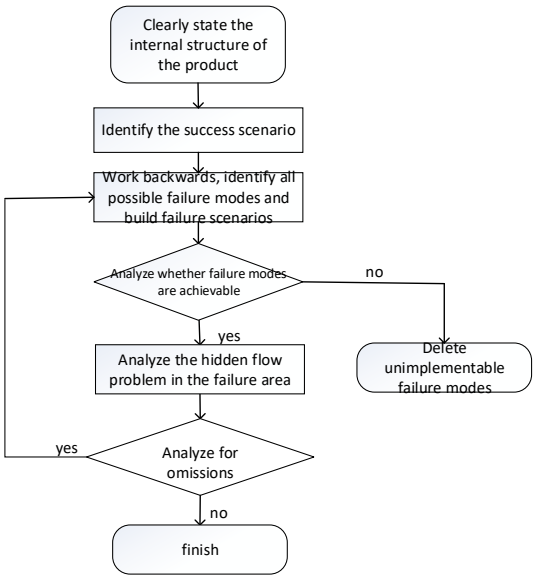

Figure 2. Failure prediction process based on AFD-2

2 Expression of flow problem based on Petri Net

2.1 Introduction to Petri net theory

In order to express the extensive and complicated interaction in the complex technical system, this study uses Petri net to model and describe the system behavior. Petri nets are strict mathematical expression and intuitive graphical expression.

Let N=(S,T,F,K,W,M) be the Petri net expressing the behavior of complex system, then :S and T are two disjoint sets (they can be assumed to be finite sets in general), and they are the basic element set of net N. The element of S is called s-element or place, which is called position in the behavior model. The element of T refers to t-element or transition, and F refers to flow relation within the network, which is represented by directed arc.

Sigma satisfies the rule of transition,M for the identity

For T ∈T, the condition of M[t > is

$$\forall s \in {}' t: M(s) \geq W(s,t)$$

$$\forall s \in t' - {}' t: M(s) + W(t,s) \leq K(s)$$

$$\forall s \in t' \cap {}' t: M(s) + W(t,s) - W(s,t) \leq K(s)$$

2.2 Conversion Rules

To map functional structures to behavioral models, the following mapping rules are proposed:

1. Establish the initial state and end state of product operation.

2: The initial state corresponds to a library, which is the initial library, the end state corresponds to a library, which is the end library, and the other libraries reflect the state after a change in the system.

3: Transition indicates that a certain change has taken place in the system, reflecting a process. After the transition is the state of the system at a certain moment, that is, the repository.

4: The components of the products corresponding to the library, namely the product components, the library is not directly connected to the library, and the change is not directly connected to the change.

5: Each transition corresponds to each function element, the input of each function element corresponds to the output of the previous library, and the output of each function element corresponds to the input of the next library.

6: In the behavior model, the input and output keep changing at all times, and the entities of the input and output are streams.

2.3 Accessibility analysis

Accessibility is the most basic property in Petri net, and all other properties are defined by accessibility.

Let N=(S,T,F,K,W,Mo) be a Petri net. If tT exists, make [t, then it is called subreachable. If transition sequence and identity sequence exist, then it is called subreachable. The set of all identifiers that are reachable is denoted as.

2.4 Formal expression of implicit flow problem based on Petri Net

Flow problems can be divided into four types: excessive flow, flow loss, flow retention, and flow deterioration. refers to the failure of flow to produce expected effects in the process of transmission and transformation.

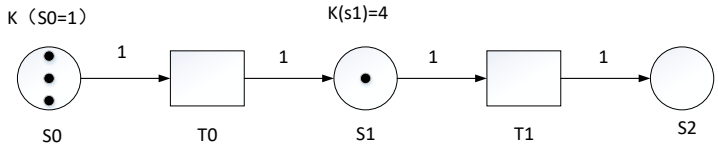

Figure 3. Stream retention

Stream hold up or stream blocking: Flow because of its own or external factors influence each other temporarily or permanently stop, reduce the type of flow in number, the failure mode is called flow stranded or flow obstruction, mapped to Petri net system, in as shown in figure 4, because the T0 set after the existing three markers in the P1 if the t1, P1 into two tags, Then M(Si)+W(t,si)≥K (si) occurs, where I >=0. The transition rule is not met, so T1 cannot occur under the current identity. This condition is called flow stagnation or flow congestion, such as heavy traffic on busy city roads.

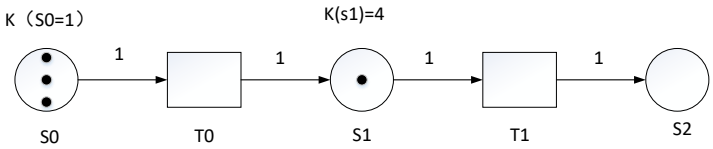

Figure 4. Excessive flow

Excessive flow: Indicates that the value of the corresponding attribute of the flow exceeds the normal function range. This failure mode is called excessive flow. At P0, M (Si) > K (Si), where I >=0, it does not conform to the rules of transition. Excessive flow will result in adverse effects, such as the voltage and current of electrical products exceeding their rated range, resulting in product damage. For example, in daily life, excessive voltage of electronic products leads to product damage, and excessive rainfall leads to flood.

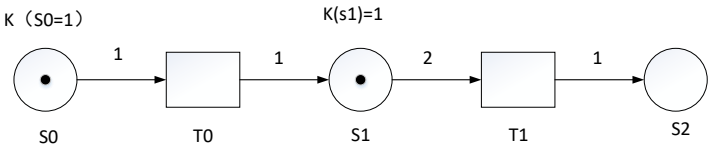

Figure 5. Flow loss

Flow loss: this failure mode is called flow loss when the value of the flow attribute in the product is below the range of normal function. It is mapped to the Petri net system as shown in Figure 5: M (Si) < W (si,t) where I >=0, which does not conform to the rules of transition. The adverse effects of flow loss include low flow conversion rate and energy consuming elements. For example, if the amount of gasoline is too low, the car will not start properly, and the cell phone battery is too low, resulting in shutdown.

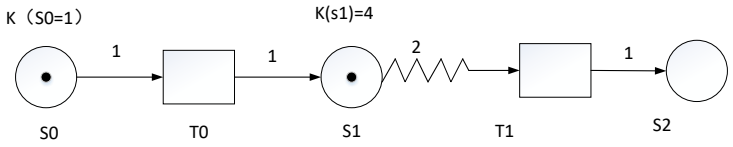

Figure 6. Flow deterioration

Flow deterioration: Internal factors lead to the output flow state and attributes are not expected, and then flow deterioration occurs, making some or all functions of the system invalid. To the Petri net system, as shown in the figure 6 .

3. Flow problem solving measures based on flow evolution law

Aiming at the above four flow problems, a flow problem solving strategy based on the flow evolution law is proposed. The flow is divided into excessive flow, insufficient flow and harmful flow in the flow evolution law, among which insufficient flow is divided into conductivity defect and utilization defect. The corresponding improvement measures are 14 and 9 respectively, and there are 18 harmful flow solving measures. Excessive flows are often classified as harmful flows to solve the problem.

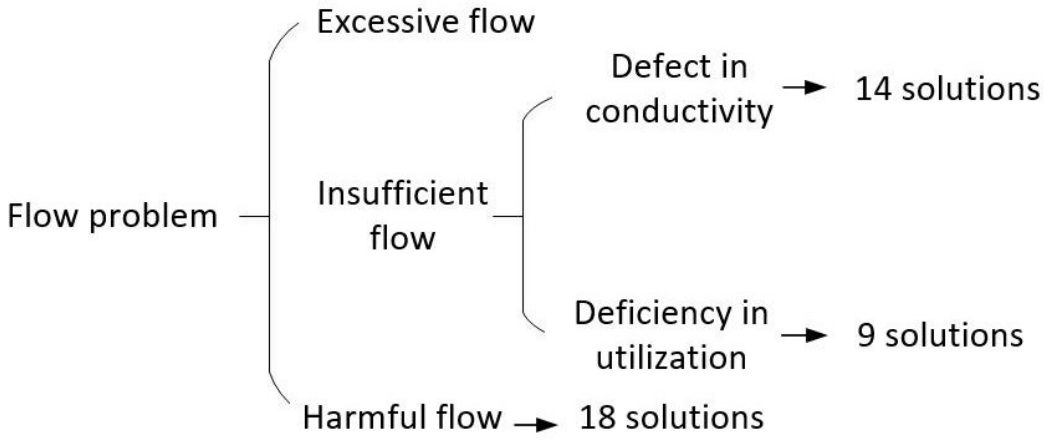

Figure 7. Flow problem solving measures based on flow evolution law

3.1 Process model of product hidden flow problem mining and solving:

The following figure shows the process model of mining and solving hidden flow problem.

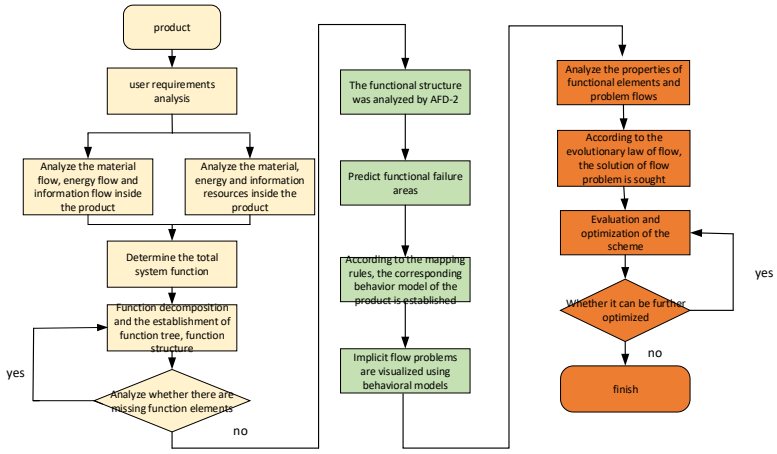

Figure 7.Process model of mining and solving hidden flow problems

(1) Select a product and conduct user demand analysis on the product.

(2) Analyze the internal and external resources of the product, determine its material resources, energy resources and information resources, and determine the material flow, energy flow and information flow within the product according to the resource type.

(3) Determine the total function of the product, decompose the function, establish the corresponding function tree and function structure, and analyze whether there are left function elements. If not, go to the next step; if yes, go back to the previous step. Afd-2 analysis was performed on the functional structure to predict the functional failure area.

(4) According to the mapping rules from functional structure to Petri net, the corresponding behavior model of the product is established based on the functional structure.

(5) Conduct an accessibility analysis of the behavior model to determine the behavior failure area, determine the hidden flow problem in the product through mapping, make the hidden flow problem explicit, determine the failure area, and excavate the obvious hidden flow problem from the failure area.

(6) Categorize the explicit and implicit problems, establish a list of multi-flow problems in the system, and elaborate the relevant meanings of flow problems. The flow problem solving strategy based on flow evolution law is used to solve the flow problem, and the solution is obtained and summarized.

5 Case Analysis

In recent years, with the improvement of people's living standard, the phenomenon of aging population is becoming more common, ability to care for the elderly life gradually decline, loss of their ability to exist to varying degrees, in view of the above problem, in the face of nursing bed products of this kind of problem arises at the historic moment, the nursing bed can satisfy the user's basic requirements, such as carry back, leg flexion, However, these nursing beds can only help patients to complete some activities in bed, but can not let the patients to outdoor activities, can not well meet the requirements of users.

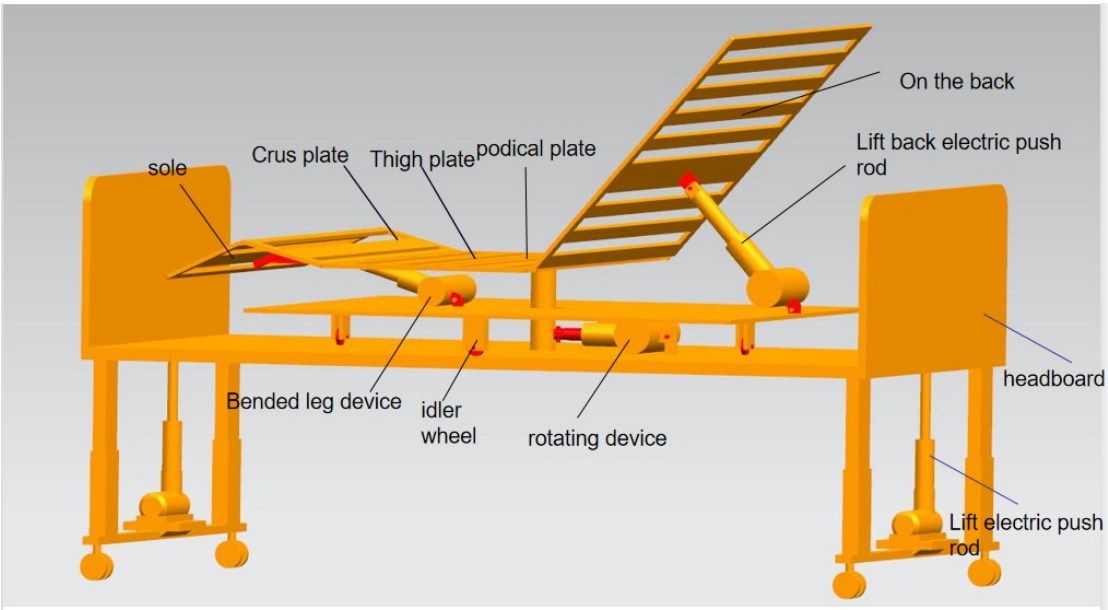

Figure 8. Schematic diagram of nursing bed

For patients who are incapacitated or unable to move, there are many inconveniences in the process of daily care or movement. In hospital and home care facilities, long-term bedridden elderly or disabled (hereinafter referred to as caregivers) not only needs to carry dorsiflexion leg etc to relieve the discomfort compared to lie low for a long time, still need to be caregivers through such as wheelchair, transferred to other places, to other activities, such as eating, watching TV and so on, which requires at least one nursing staff to transfer the picked up to a wheelchair.Not only is it a heavy load for caregivers, but it also increases the risk of accidents for caregivers. In view of such problems, this paper analyzes an existing nursing bed, which is easy to install, covers an area of small and easy to operate, suitable for use in the traditional family environment. However, the mechanical structure stability of the product is poor, and there are hidden safety risks, maintenance is difficult, and the failure rate is high, now the method described above is used for analysis.

(1) Analysis of user needs Nursing bed design should fit the user's use requirements, that is, to meet the requirements of use. Through market research, questionnaire survey, interview

and other methods, design requirements were put forward, and relevant technical levels were considered as design constraints, and the design task book was obtained, as shown in Table 1.

Table 1. Nursing bed design task list

Nursing bed requirements	Be sure to meet your requirements/desires
cheap	wish
Good structural stability	Will reach
Easy to operate	Will reach
Can bed, chair separation	Will reach
You can wash bath	wish
Bearing > 500 kg	Will reach
To save energy	wish
Small footprint	wish
Easy maintenance	Will reach
Long service life	wish

For example, according to the needs of users, the use of performance needs to be improved, the main use of the existing products is unable to separate, the current care bed can only meet the user's rest, back lifting, bending legs and other requirements, can not meet their entertainment, outdoor walking requirements. The structure is not stable enough and the service life is short. In the power source selection, the plug-in power source as the power source, the overall structure is simple, the use of space is limited, difficult maintenance, high cost. Therefore, it is necessary to improve the intelligence degree of the existing product system, improve the user experience, and make it more convenient to operate.

(2) Analyze the material flow, energy flow and information flow inside the product to determine the material resources, energy resources and information resources inside the product, as shown in Table 2 and Table 3 below.

Table 2. System Resource Analysis

The resource type	Resources that exist in the product
Material resources	Chair back electric push rod, flexion leg electric push rod, rotating electric push rod, chair back plate, hip plate, thigh plate, leg plate, foot pedal, wheelchair control box, universal wheel, rear wheel, pedal link, flexion leg link, first chair frame, second chair frame, handle, roller, chute wheel, small pulley,By caregivers
Energy resources	Electric heat energy, mechanical energy, joule heat
Information resources	Signal, the chair gesture

Table 3. System flow analysis

Flow type	The flow that exists in the product
Material flow	By caregivers
Energy flow	Electric energy, heat energy, mechanical energy, joule heat
The flow of information	Signal flow

(3) Determine the total function of the product, which is described as the object of nursing use. The input of the total function is electric energy and signal, and its output is heat, position, posture and signal.

(4)

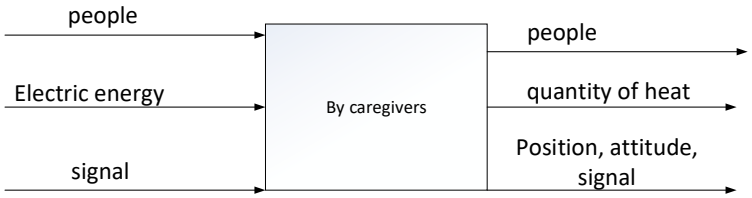

Figure 9. Total function diagram of nursing bed

Decompose the total function of the product, and use the function base to establish the function tree. Each layer of decomposition should be based on the user's needs to ensure that these sub-functions meet the needs of all users.

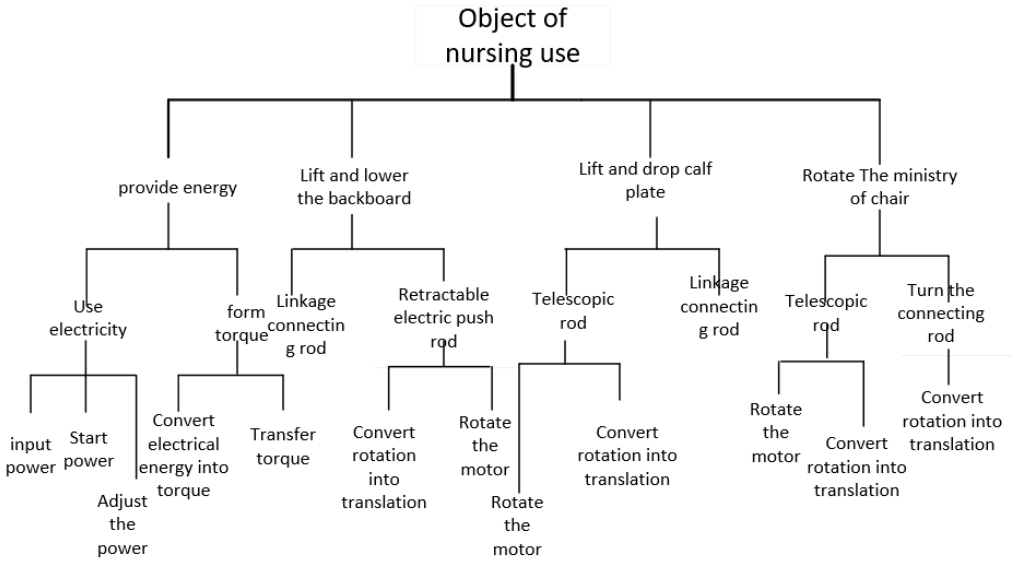

Figure 10. Nursing bed function tree

Introduce the flow, trace the material flow, energy flow and information flow from the bottom of the function tree, and establish the function chain of each input flow. The product functional structure is connected to each function chain and combined with repeated parts. On the premise of ideal state, the product can effectively care the user's work, Anticipatory Failure Determination(AFD), the system ideal inversion, the nursing bed can't normal users mainly events M, summarizes several forms of the reverse condition, combining with the system function structure model, find out each form the corresponding functional failure and loss, As shown in Figure 11. Thus, the loss area can be predicted.

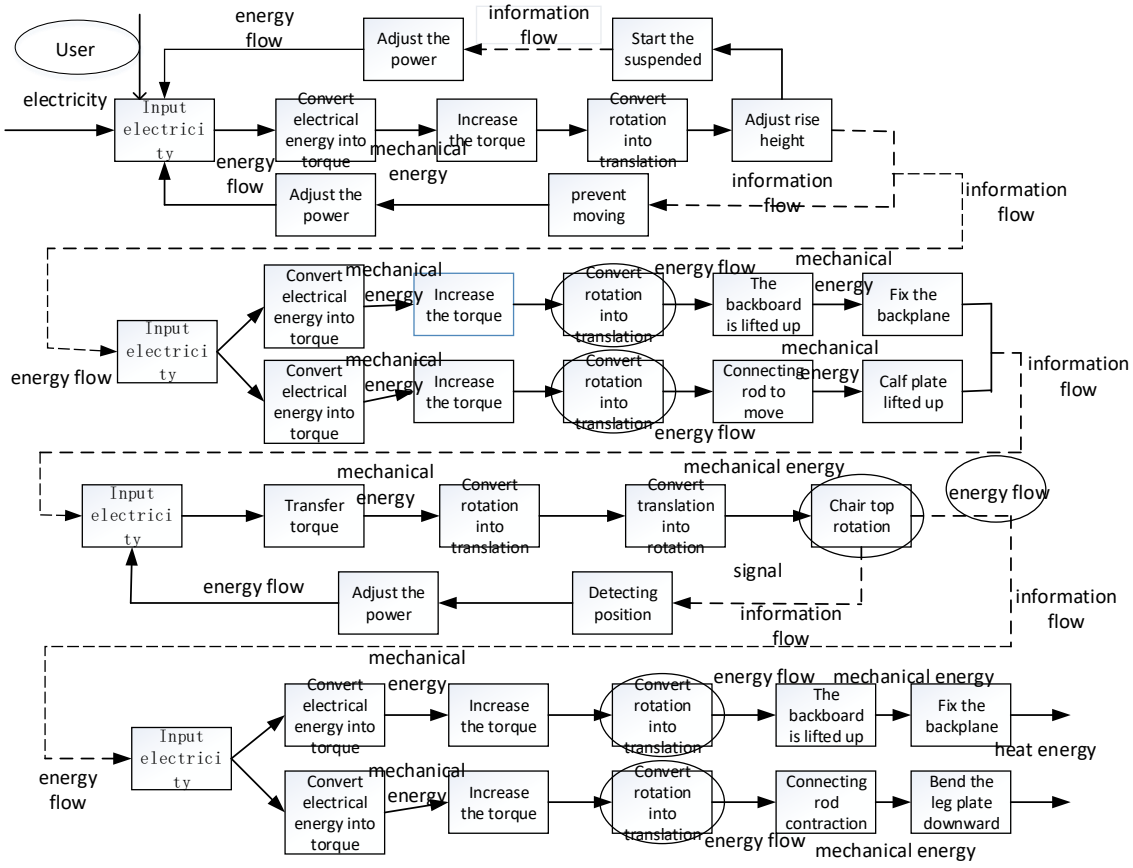

FIG. **Figure 11. Functional structure of nursing bed**

Table 4. Failure modes and analysis

The expression of the reverse state	An imaginary method of implementation	Realization possibility and function failure mode determination	Failure area corresponding structure	Failure type and analysis
Unable to achieve leg flexion, rotation, lift back and other functions or insufficient function	Lack of electricity	Insufficient power supply, motor idling, flow loss, can be realized	Structure of each part of nursing bed	The design defect and low voltage ensure the safety of nursing bed, but affect the normal use of nursing bed
	Excessive electricity	Coil short circuit or short circuit, excessive flow, can not be achieved	Electric push rod section	Defective design, faulty supply voltage
Nursing bed vibration, shaking and other conditions	The person being cared for is overweight or has an incorrect posture	Nursing bed use object weight is too large, excessive flow, can be realized	The chair part	Design defects, the user's weight is too large, nursing bed can not work stably
Part of the nursing bed structure was damaged	Error in position signal	When the signal in place is deviated, the interference flow of some part of the nursing bed is insufficient in space, which can be realized	Structure of each part of nursing bed	Design conflict, travel process should be accurate, otherwise it will form interference
	Joules are overheated	The excessive joule heat produced by rolling friction damages the nursing bed, and the flow retention can be realized	rotating part	Design defects, Joule heat generated during rotation should be reduced

(3) According to the above mapping rules, first determine the initial state. The initial state is the lifting state to be started and set as S0. After this state, connect a function element, namely, the input electric energy, and set as T0. And so on, gradually transforming functional structures into behavioral models.

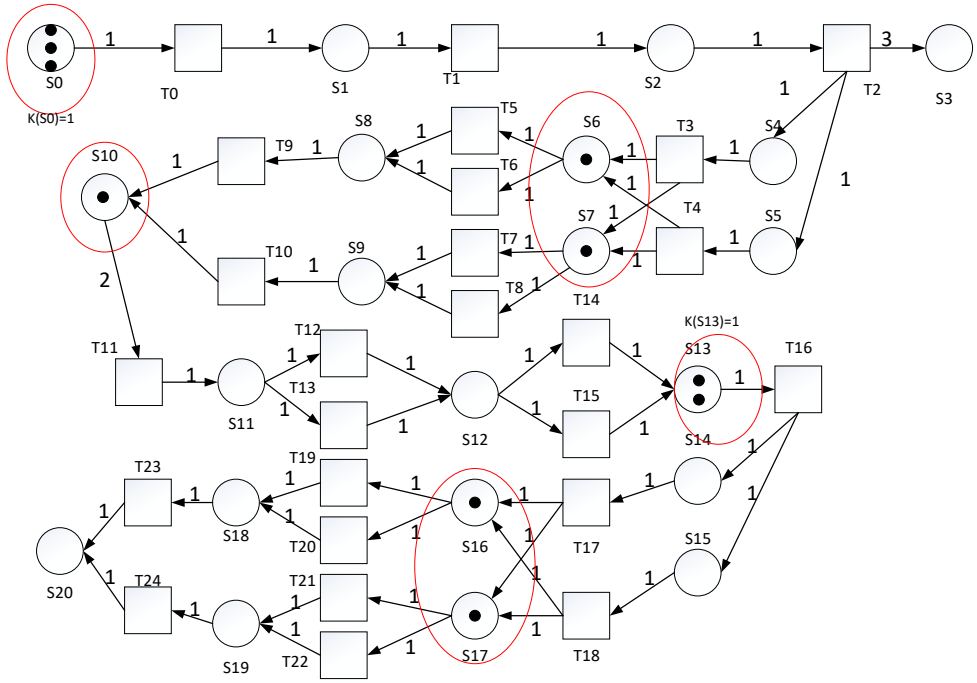

FIG. 12 Nursing bed behavior model

Table 5. Physical meaning of library and transition

Sign	physical meanings	标记	physical meanings
S0	Lift state	T0	Input electricity
S1	Electric pushrod is dynamic	T1	Start the lift
S2	Queen form of bed frame	T2	The detection in place
S3	After bed chair separation	T3	Input electricity
S4	After of of electric push rod	T4	Input electricity
S5	Start the back electric push rod after the start form	T5	The calf plate rises
S6	Link working state	T6	The back plate rises
S7	Push bar working state	T7	Stop rising
S8	The detection in place	T8	Stop rising
S9	The detection in place	T9	Link linkage

S10	Rotary motor start dynamic	T10	Push rod linkage
S11	Link working state	T11	Input electricity
S12	Rotation state	T12	The center axis turns
S13	The detection in place	T13	Link rotation
S14	Fleow leg electric push rod dynamic	T14	Limit signal
S15	Start back electric push rod start dynamic	T15	Rolling wheel rotation
S16	Link working state	T16	despin
S17	Push bar working state	T17	Input electricity
S18	The detection in place	T18	Input electricity
S19	The detection in place	T19	The calf plate drops
S20	Non-rest state	T20	Linkage work
T21	Stop rising	T22	Stop falling
T23	The calf plate drops	T24	Stop rising

（5）The reachability analysis was conducted on the behavior model, and the implicit flow problem in the product was determined by mapping, as shown in Table 6. The implicit flow problem was made explicit by the behavior model, as shown in Figure 12.

Table 6. Analysis results

Problem areas	Failure modes	Corresponding flow problems	Flow problem type	
S0 (Excessive body weight)	excessive	Excessive flow	Hidden flow problem	Material flow problem
S6, S7, S16, S17 (insufficient power)	insufficient	Insufficient flow	Hidden flow problem	Energy flow problem
S10 (Error in position signal)	insufficient	Insufficient flow	Hidden flow problem	Information flow problem
S13 (Excessive joule heat)	excessive	Excessive flow	Hidden flow problem	Energy flow problem

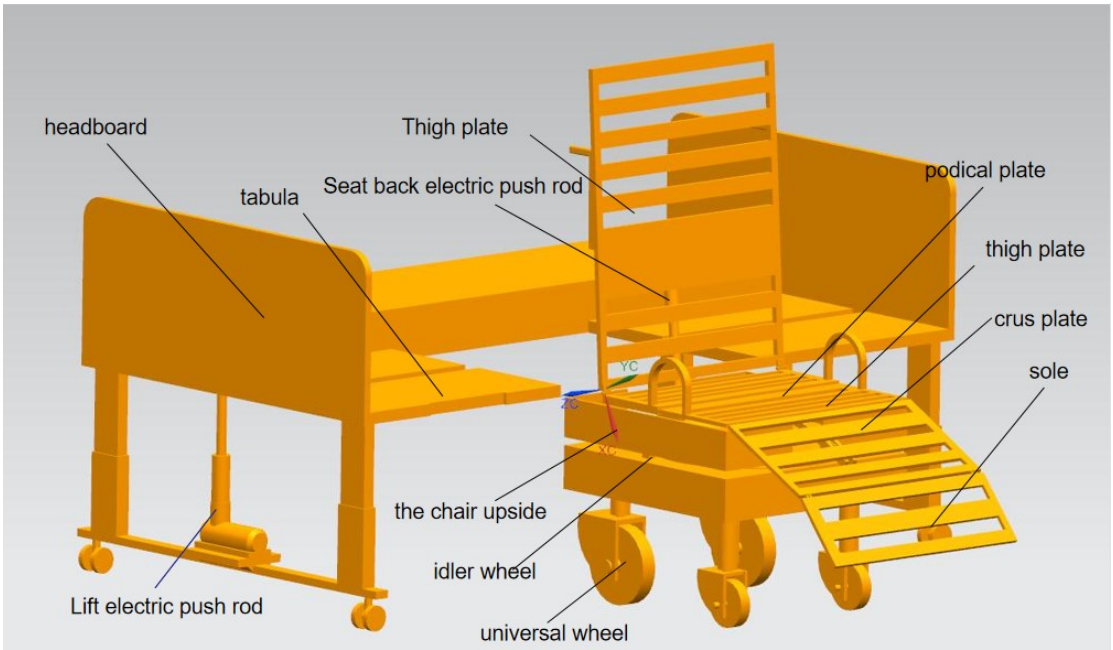

Figure 13 Nursing bed concept scheme

By dividing the bed into lifting part and wheelchair part, the plan realizes its separation function, and well realizes the user's rest and entertainment requirements. At the same time, the improvement of the rotating structure and flexion leg structure also improves the stability of the system structure. To save space, the improved behavior model and subsequent failure analysis and verification are omitted. The analysis results meet the predetermined functional requirements. The prototype model is shown in Figure 13.

Conclusion

(1) Study the implicit flow problem in products. The explicit flow problem and the implicit flow problem are distinguished. Combining AFD - 2 on the analysis of the function structure, function of predicting the failure area, mining internal contain hidden flow problem, and put forward the mapping rules, to translate into behavior model, function structure through accessibility analysis to determine failure district of the behavior, and the mapping to determine problems hidden flow inside the product, the performance of the model be made explicit implicit flow, Finally, the types and properties of the flow problem are analyzed and the solution of the flow problem is obtained by solving the flow problem strategy based on the flow evolution law.

(2) The analysis and process model of implicit flow problem are established to provide a regular process for subsequent product innovation. Taking nursing bed as an engineering case, the innovation scheme of the product was obtained, and the validity of the model was verified. Due to the dynamic, complex and hidden nature of the flow problem, the mining and solving path of the flow problem and the dynamic solution strategy need further research.

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Technology Innovation of Green Regenerative Hydrogen Economy and Electrolytic Energy Storage

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Abstract

The greenhouse effect continues to rise in this century, so it has become a global consensus to reduce carbon dioxide emissions through various methods. So far, developing green and renewable energy sources has been the main goal. However, the main problem with renewable energy is the instability of power output affected by seasonal and environmental factors, which will lead to the difficulty of grid management. The advantage of Proton Exchange Membrane Water Electrolysis (PEMWE) as an off-peak energy storage lies in its high current density, high purity gas generation and modular system. In addition, the use of green hydrogen in various highly polluting industries is seen as the last mile towards net zero carbon emissions.

We as a research team of Taiwan Yuan-zhi University fuel cell and hydrogen center for the Ministry of Science and Technology of production-academy of small alliance plan during two phases (2013~2018) subsidies, focusing on the fuel cell industry service platform to assist industry technology development, has accumulated bright spot achievements, including: complete alliance site settlement, deepen the network platform communication, achieve alliance members' technology transfer, patent sharing and authorizing each other. We contribute to provide local technical consulting services, improve the research and development level of manufacturers, enhance the international competitiveness of products, review the industry product specifications and parts costs, and assist alliance manufacturers in small-scale commercialization of products such as multi-purpose hydrogen production machines and proceeding testing systems.

Keywords: green hydrogen, fuel cell, proton exchange membrane water electrolysis (PEMWE)

1. Foreword

In the COVID-19 outbreak, countries reduced the spread of pneumonia and casualties by lockdown, working at home, and reducing travel and transportation, thus greatly reducing energy use and carbon dioxide emissions, indirectly slowly restoring the natural environment, which shades the sky blue, the water clean, urbanite-seeing rare large wildlife. According to International Journal of Energy Research Editor-Ibrahim Dincer, the COVID-19 outbreak sounded the death knell of the carbon economy (Carbon Age) and was replaced by the hydrogen energy economy (Hydrogen Age [1]) that regulates the stable power supply of renewable energy. In 2021, Japan excluded the serious epidemic and public opposition, held the Olympic Games and opened the first hydrogen torch in history, which is a symbol of Japan's efforts to lead the world into the green hydrogen economy generation.

In the past decade (2009-2019), solar photovoltaic plant capacity has increased nearly 30-fold (from 23GW to 627GW), and wind power generation has nearly tripled (from 198GW to 743GW). In terms of the price of LCOE (levelised cost of electricity) over the decade from 2010 to 2020, Global offshore wind prices fell by 54% (from $0.162 / kWh to $0.084 / kWh), Solar photovoltaic power generation prices fell by 85% (from $0.381 / kWh in 2010 to $0.057 / MWh in 2020), which is nearly close to the cost of petrochemical fuel power generation, [2].

Due to the seasonal power generation characteristics of renewable energy, various energy storage devices are born, among which the electrolysis of Green Hydrogen and pumping storage of long and large-scale energy storage are the most concerned. McKinsey stated that more than 30 countries announced green hydrogen blueprints in 2021, with more than $70 billion in public investment. Breakthrough Energy Ventures (BEV), which specializes in climate change technology innovation, raised $22 million for Israeli green hydrogen startup H2Pro in March of 2022. The production cost of Green Hydrogen in 2019 is USD $2.5-4.5/kg[3], the current cost of hydrogen production is 2-3 times of petrochemical fuel cost(Gray Hydrogen). In the future, the cost of renewable energy generation will fall to USD$30 / MWh by 2030 (Offshore Wind, for example), facilitated by mature mass production using hydro electrolyte technology with (USD$300 / kW) , which can make the green hydrogen production cost close to the cost of petrochemical fuel production, USD$1.5-3.0/kg. By 2050, Green Hydrogen costs will be reduced by up to USD$1-1.5/kg, less than the production cost of traditional petrochemical energy, It can replace coal, natural gas and heat energy used in industrial products such as steel and cement on a larger scale. Among various electrolytic technologies, Proton Exchange Membrane Electrolyzer (PEME) technology has the advantages of low temperature operation, molecularity and high efficiency, and its number of construction pieces invested in recent years since 2017 is higher than other electrolytic technologies of ALK and SOEC[4]. Green Hydrogen has the characteristics of the current main green energy, which can be used to help heavy industry, large transportation, and blast furnace smelting steel operation which is the most difficult to reduce carbon making to achieve emissions

targets by the world in 2050 in the effort of the last mile.

2. Innovation of Our Team in Yuan-zhi University

Since 2000, Our team in Taiwan Yuan-zhi University has integrated the cross-department research team and built a fuel cell center, which has the most complete cross-field fuel power team in the academic field of Taiwan, including experts and professors of machinery, chemical industry, motor and management economics. By the support of Taiwan Economic Affairs Department, Taiwan Science and Technology Affairs Management Department and Taiwan Education Affairs Department, our team in the University has completed nine standard fuel cell laboratory, covers an area of about 600 levels ground, and purchases testing and research analysis equipment more than 100 million yuan, which is the most complete, perfect fuel cell of hydrogen research and testing center in Taiwan.

Since 2006, our team in the center has been supported by Taiwan's Education Affairs Department to the top university program and top research center program, to strengthen the research and development of high and low temperature composite membrane, membrane electrode groups, micro sensors, metal and composite bipolar plates, hydrogen storage materials, low temperature catalyst and so on. According to Scopus Citations, our center has published 683 SCI papers in the field of fuel cell and hydrogen energy, with a total of more than 3,000 references cited, ranking an academic top position in all important fuel cell and hydrogen energy research centers in the world. At the same time, we program a complete patent layout, which has obtained 56 patents at home and abroad, and will continue to spread the industry technology in the future. And in 2020, our center won the Future Science and Technology Award, and also won Taiwan Science and Technology Affairs Management Department subsidies for successful university for holding the "2020 Green Drone Innovation Grand Prix", additionally won the "Other Green Power Drone Group" final 7 km champion, and also won Guishan island 25 km challenge runner-up.

Our team has mastered the key technologies for three areas, including:
A. Key technology of PEM electrolysis components, B.Design and development of PEM electrolytic reactor, C.Hydroelectrolysis system development. The details are as follows:

A. Key technology of PEM electrolysis components

(1) Key technology of membrane material
The fuel cell center of Yuan-zhi University has put into the development of porous PTFE-Nafion composite film materials. The mechanical strength, gas permeability and heat resistance of the produced film materials are better than those of DuPont Nafion-112. If it is used for DMFC, the performance can be much higher than that of Nafion-112 and Nafion-117 due to the low methanol penetration rate. Our center has successfully made a PTFE / Nafion composite film and achieved

good low temperature (<90°C) fuel cell performance. To increase the operating temperature of the PTFE / Nafion composite membrane fuel cell, TEOS (tetra ethoxy silane) is imported in the Nafion / PTFE composite membrane, or embedded with nanosized inorganic particles, Zr (HPO4) 2. At a temperature between 100 and 130°C, PTFE / Nafion / TEOS and PTFE / Nafion / Zr (HPO4) 2 composite films have better proton exchange membrane fuel cell (PEMFC) performance than pure Nafion and Nafion / PTFE films. In addition, our center has also been engaged in high temperature proton exchange membrane fuel cell (HT-PEMFC) development for several years, the related PSi-EP / PBI proton exchange membrane can be applied to 160 and 210°C of proton exchange membrane fuel cells.

In recent years, the proton exchange membrane water electrolytic cell (PEMWE) has been studiedin our center, and the performance and durability of nano inorganic particle Zr (HPO4) 280°C proton exchange membrane hydro electrolytic cell embedded in Nafion membrane have been significantly improved. At present, the liquid flow battery membrane material related research is also under way. Proton exchange membrane fuel cell, proton exchange membrane water electrolytic cell, and the flow cell of battery possess almost the same membrane, mainly with perfluorsulfonic acid polymer, but due to different battery operating conditions, there exists lightly different membrane. Now, the domestic and foreign literature of PEM application focuses on the fuel cell, but the method of water electrolytic cell environment is more severe, its high humidity, high acid, high voltage, and high pressure feed cause much more challenging. According to our previous fuel cell membrane for years of experiences, our center has been devoting to the related research of proton exchange membrane water electrolytic cell and flow cell membrane.

(2) Synthesis technology of catalyst and carrier

Since Oxygen Evolution Reaction (OER) is a limiting factor for the efficiency of proton exchange membrane water electrolysis (PEMWE), because the reaction of splitting water molecules is mainly subject to the slow dynamics of the OER 4 electron coupling mechanism. Therefore, an effective OER electrochemical catalyst is the key to the electrolytic performance. The current cost of PEMWE hydrogen production is still high, and 24% of cost comes from the Membrane Electrode Assembly (MEA)[5]. MEA usually contains micro scale precious metals, mainly Pt and Ir, to effectively catalyze the Hydrogen Evolution Reaction (HER) and OER, respectively. At the present stage of the research and development results, the OER activity containing Ir and Ru oxides is generally better. RuO2 has a relatively high activity, while IrO2 has a better long-acting stability [6]. In the acidic environment of PEMWE, the carrier of OER catalyst is not suitable for the carbon substrate material because the high oxidation potential of operating conditions can easily lead to the anode generated oxide film and the corrosion of the carbon substrate material. In order to effectively reduce the cost, improving the activity, utilization, durability of chemical catalyst and developing non-precious metal catalyst have been the mainstream research direction.

Electrochemical catalyst synthesis method of precious metal oxide commonly includes chemical reduction method, microwave-assisted heating reduction method, Adams fusion method and hydrothermal method. To reduce the amount of precious metals, we can use a large specific surface area of the carrier. Although carbon black is a common catalyst carrier, however, in the strong oxidation environment of water electrolysis, carbon materials are prone to corrosion, leading in the accumulation and migration of precious metals on the surface, and even exfoliation. Therefore, many conductive metal oxides (such as TiO2, SnO2, etc.) are considered as alternative materials for carbon black. At present, our laboratory mainly has Adams fusion method in PEMWE catalyst synthesis technology, other synthetic experiences include hydrothermal method, chemical reduction, and microwave assisted heating reduction method. In the catalyst carrier, in addition to graphene and nanocarbon tubes, metal oxides of different structures, such as titanium dioxide nanofibers, titanium dioxide nanoparticles, and Sb-SnO2, which have been gradually developed in recent years. In addition, our laboratory also aims at the development of non-precious metal catalyst technology nowadays.

At present, the catalyst or MEA used in the field of proton exchange membrane fuel cell (PEMFC) or proton exchange membrane water electrolysis (PEMWE) is almost exclusive by several foreign manufacturers. In addition to being quite expensive, many key technologies are also unclear; for example, in the catalyst synthesis technology, slurry preparation and MEA composition, etc are uncontrollable. This will cause research inconvenience, and the research and development results will be subject to raw material suppliers. Therefore, the development and diffusion of this technology can not only cultivate the catalyst research and development manpower of related industries and improve the industrial technology energy, but also implement the root of local technology. In the case of limited resources and increasing cost, the development of related technologies can improve the activity of existing catalyst and enhance the competitiveness of PEMFC and PEMWE industry in the market.

(3) Membrane electrode group coating technology and assembly integration

The membrane electrode group with anode and cathode coating technology is utilizing with the scraper or ultrasonic spray method as the main process. The scraper can be replaced through the front end blade and can be divided into slit type of Slot Die Coating and scraper type of Blade Coating. Ultrasonic spraying technology can make the catalyst be evenly distributed in the reaction area, and make the catalyst sauce particles meticulous to avoid the material clustering due to the influence of additives. The scraper can reduce the cost of the equipment and reduce the consumption of the reactive catalyst material. Through the ultrasonic spraying method or scraper coating method, we establish the standardization of manufacturing process and composition ratio optimization to assist the industry manufacturers in the production process, to reduce the cost and improve the production yield of the membrane electrode group, and to increase the flexibility of product development, not bound by the existing commercial purchase specifications [6-9].

Through the full homemade membrane electrode group production process, we integrate the project of micro probe sensor, and can directly bury the micro probe sensor into the catalyst layer, and observe the membrane electrode group of internal microscopic condition such as uneven current distribution of local hot spots, and through the internal voltage and current value, we observe and judge the condition of the decline, and can provide real-time life cycle prediction. Therefore, through the production process integration of micro probes, combined with the computer board to digitize the information, transmitted to the cloud monitoring to observe the data, and the load can be automatically adjusted according to the health situation to maintain the hydro electrolyte performance output, and to protect the electrolyte from affecting the life cycle [10] due to the excessive pressure increase, temperature changes and flow changes.

B. Design and development of battery stack

(1) PEM electrolysis of long-effect porous titanium collector plate (porous transmission layer) coating technology

Operating environment under high pressure and high voltage, stronger mechanical structures are demanded. And the electrolysis process produces acidic substances, corrosion resistance is also one of the important conditions of the gas diffusion layer substrate, Titanium substrate has both of these two characteristics. Therefore, it is widely used in hydroelectrolysis batteries or stacks, used as a gas diffusion layer for a substitute of carbon substrate. However, the titanium substrate forms an oxide layer on the surface, which has a high adhesion and arrangement density, thus protecting the metal substrate from oxidation. This passivation effect is a negative effect for the overall hydrolysis system. The passivation layer itself is a non-conductor or a semiconductor, in which the impedance size depends on the thickness of the passivation layer, which can be up to hundreds of nm thick, which affects the performance of the electrolyte device. In addition, in the ozone production it is more stringent than the hydrogen production environment, in addition to the applied potential being increased to double, and the strong oxide ozone produced, which tests the stability of the material itself [11,12].

We treat titanium substrate through oxalic acid etching, tin and antimony in the form of electrode position, which are sent to high temperature furnace for oxidation treatment to form antimony mixed tin oxide (ATO) on the surface of the titanium substrate, and in the post processing part through electrode position coated nickel material on the substrate, to form a conductive corrosion layer under the harsh environment of hydroelectrolysis ozone with continuous operation for 200 hours, which can degrade 23mA per hour to provide homemade and long-acting porous titanium collector plate technology [13-15].

(2) PEM electrolytic metal bipolar plate technology

Owing to PEM hydroelectrolyzer with the high operating voltage and the carbon material

oxidation and corrosion problem, the catalyst / carrier, diffusion layer and the flow field bipolar plate material are designed and used with corrosion resistant metal materials. So there is a lot in common with the current automotive fuel cell reactors. Traditional fuel cell stacks are converted from graphite to metal materials to improve mechanical strength and reduce weight and volume. Therefore, the advantages of developing PEM hydroelectrolyzers can share fuel cell technology, materials and mass production equipment, and have the potential to greatly reduce the cost of hydrogen production of hydroelectrolyzers. Combining PEM electrolyzers and hydrogen fuel cell, just like lithium battery electric vehicles and charging pile, as long as there is a web grid, we can build a hydrogenation station, and avoid the transportation and storage of hydrogen problem, it is relatively easy for hydrogen infrastructure. At the same time, it is easier to convert to green hydrogen of renewable energy in the future and achieve carbon neutrality. Our past metal reactor research results show that the fuel cells used in UAV drones can only choose the metal material bipolar plates due to the high energy density requirements. Toyota Miria fuel cell vehicles use the metal bipolar plate for precision 3D micro flow channel, which need to use precision machining mold and precision manufacturing technology. DOE Los Alamos National Energy Lab[25] has proposed to replace the metal flow plate with the metal mesh, greatly reducing the material and manufacturing cost of the bipolar plate. However, there is no good performance reactor available for the use of metal mesh. Because the metal network has a variety of commercial mass production specifications of products, its product specifications selection, matching with assembly and operation conditions, which greatly affects the performance of the battery. Recently, we used commercial purchase specification titanium mesh, with double-layer structure titanium mesh, combining with optimized compression and operating conditions, we unexpectedly obtained 3D fine mesh flow channel material surpassing beyond the conventional graphite flow channel and vehicle fuel cells.

C. PEM Electrolysis system development

With the evolution of science and technology and the popularization of the Internet, it is imperative to introduce the concept of the Internet of Things (IoT) from the development process of Industry 4.0. Through the electrolyte built-in micro sensor technology, and with low power chip system, engineers can monitor the current situation and maintenance, and eliminate the possibility of danger. From the perspective of business, hydrolysis hydrogen production system belongs to high precision technology, for safety it is not allowed to let the user to access direct operation of the machine. Through information integration and feedback, we make the system can achieve automatic control as the important technical goal. Using the microcomputer board, the default protection program can command the power supply equipment to make output adjustment to maintain the current value, and in order not to damage the hydroelectrolyzer due to the excessive voltage value, we need a voltage value threshold, that is, when the voltage value exceeds the

threshold, then we step down the voltage.

Through our center of many integrated sensors, we achieve multiple parameters measurement of voltage, current, temperature, pressure and flow to achieve the minimum cost and minimum volume. In addition to remote monitoring performance, we can maintain automatic hydroelectrolyte performance output and protect the hydroelectrolyte from reducing service life [9,16], and can measure hydrogen production and hydrogen storage cylinder stock.

Since 2000, Taiwan has invested in fuel cell related research and development. In recent years, some companies have transformed themselves to electrolysis and even developed healthcare related products. Kung-Ten company is optical communication. Since 2006, we has guided her transformation and development of PEM electrolysis technology for energy storage and hydrogen production, which was applied to hydrogen engine cleaning and hydrogen water health care. In 2011, we won the "Excellent Guidance Case" awarded by Taiwan Economic Affairs Department in 2011.

If PEM electrolysis is operated to a higher voltage (> 3.0V) with appropriate anode materials, hydrogen / oxygen / ozone can be produced and used in medical related fields. Germany's Prominent mainly uses its products in water treatment and disinfection equipment, and has medical patents for ozone regeneration therapy for kidney tissue and other organs. Japan's denora permelec has a representative country of ozone / hydrogen research for many years, the company mainly focuses on research and development of electrolysis as the core and has many related technology patents, sales products are ozone machines and electrodes, which are mostly used in semiconductor silicon chip cleaning. China's Guangyuan instrument is mainly used for people's livelihood disinfection as the core, both the use of space ozone disinfection deodorization and sewage treatment has good quality. Taiwan's representative company-Baxter environmental protection, the main core emphasizes hydroelectrolysis technology of the use of clean energy applications in disinfection and preservation. Our team in YZU has special performance in various fields of application and patents, and has many years of research results in hydroelectrolysis and the technical patents, which are above the level compared with the international level. In the application of the patent leading international layout of breeding, medical, preservation, agricultural patents, and these four fields have won the award affirmation, leading the international role. Participating in the 2020 Taiwan Innovation Expo, our patent "Medical Air and Liquid Supply System" won the highest honor platinum award ranking the first place in the mechanical category, aiming to highlight the possibility of green medical treatment of diabetes cure.

3. Epilogue

Fuel cell design and production technology has been developed in Taiwan for more than 10 years, and our research team has also cultivated a lot of research and development technical manpower. The future 2050 carbon neutrality goal will increase the demand for the application of

green hydrogen, and the original hydrogen fuel cell technology base will help transit the transformation and upgrading into green hydrogen technology.

In 2015, the international automakers has jointly declared they will synchronously produce fuel cell vehicles. By the government policy to promote the demand of hydrogen market and to develop hydrolysis green hydrogen technology component supply chain, which improves Taiwan's fuel cell technology upgrade and leads to occupy the international green hydrogen with important technology position.

Fuel cell is a power generation unit, which is used in the electric power design of products, and it is still short of hydrogen source. Through the development of hydroelectrolysis and green hydrogen production technology, the electric energy integration technology is improved and popularized. Technology promotion and integration of other renewable energy systems can be extended to other application markets, such as automotive hydrogenation stations, industrial and domestic hybrid gas, semiconductor processes etc., to enhance Taiwan's system engineering and technology integration capabilities of green hydrogen economy.

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A Study on the Purchase of Tangible Goods in Intangible Era

- Interpreting the Transition of Music Media from the Viewpoints of Value -

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Abstract

In recent years, goods have shifted from tangible to intangible under the influence of digitalization. People are drift to intangibles that are easy and convenient. On the other hand, there are those who prefer conventional tangible goods. In this study, the present age of digitalization is defined as the intangible era. The purpose of this study is to examine the psychology of consumers who choose tangible goods in this age of digitalization. This paper will conduct a review of articles on value research and develop a framework for value. In addition, this paper takes up music media as an example of digitized goods in this research and investigate their transition. When we think tangible goods buyer from framework for value and music media transition, it was concluded that tangible goods buyer has sensory value, convenience value, and self-expression value the framework which include 35 values. These values are in the psychological period and important to buyers of tangible goods in the intangible era.

Keywords: Value, Tangible, Intangible, Music Medium

1. Introduction

In recent years, digitalization is progressing, and things have changed from tangible to intangible. The following are examples of digitization: Music and video distribution, Internet shopping, cashless payment, etc. Music and video streaming, which in the past involved purchasing media such as CDs and DVDs, have been converted to data and consolidated into applications such as Spotify and YouTube. Using them via smartphones and computers is the mainstream. The number of users of Internet shopping and cashless payments is increasing because non-contact measures are required in the wake of the epidemic of the COVID-19 (Ministry of Economy, Trade, and Industry, 2021). It can be said that the digitization of goods is enriching people's lives because it can be used anywhere and anytime and is convenient. Digitalization of present times can be called the intangible era. In the intangible era, there is a change from tangible to intangible, and to provide is to disregard tangible goods because it is decrease in demand and sales. The challenge is that tangible goods in the intangible age are updated in one medium, so there is no need for several mediums, and therefore unnecessary

items are quickly discarded (MOTTAINAI, 2021). Taking music media as an example, the current situation is the reduction of Compact Disc (CD) production and sales. According to the CD production results of the Recording Industry Association of Japan, the total number of Japanese and Western editions in 2010, called the peak of CD sales, decreased from 206,539 copies in 2010 to 103,552 copies in 2021 (Fig.1). However, it does not become zero and it can be said that a certain percentage of users are purchasing (The Recording Industry Association, 2021). Under such circumstances, there is an increasing movement to utilize things without waste by the environmental 3R policy (Reduce, Reuse, Recycle) due to the "MOTTAINAI" spirit peculiar to Japan. The Japanese word "MOTTAINAI" is being disseminated overseas in a world where SDGs (Sustainable Development Goals) and environmental considerations are being considered (Ministry of Economy, Trade and Industry, 2021) (MOTTAINAI, 2021). In this paper, the present age when digitization progresses from such problem recognition is referred to as the intangible era. And the purpose is to consider consumer sentiment when choosing tangible goods in this era.

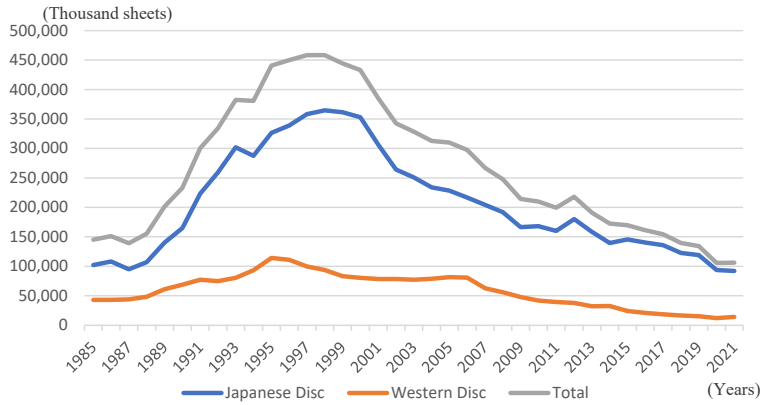

Figure 1 Production Volume of CDs (The Recording Industry Association)

2. Development of Analysis Framework

For literature review, search was conducted using Google Scholar, an article search site, using the following keywords: "value," "intangible," "tangible" and "consumer". Among them, conducted a survey of papers with the word "KACHI (in Japanese)" or "Value" in the title of the paper. Then, it organized a total of 16 papers, seven in Japanese and nine in English. 52 values are arranged chronologically and can be divided into three periods about every 10 years as shown in Table 1. Initially, the 1980s to the 1990s were defined as the behavioral period (Areas in blue). This period was defined as the behavioral period because the values in this period described the essential meaning of words and daily actions. The period from 2000 to the early 2010s was defined as the psychological period (Areas in pink). The values of this period were defined as the psychological period because they were used in papers on the psychology of people, such as brands and consumers. The period from the late 2010s to 2020 was defined as the environmental period (Areas in yellow). Many of the papers from this period describe changing culture and tradition, and value is created from the surrounding environment, so this period was defined as the environmental period.

Table 1 Value transitions in value research

Author / Era \ Value Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	Number of values appeared
Mochizuki	1981	1	2	3																																																		3
B.Philip	1995				1	2	3	4	5	6	7	8	9																																											9
C.Bernard	1997			1										2																																									2
Ueda	2004														1	2	3	4	5	6	7		8	9	11	12	13																												12
Nobeoka	2006														2							4		5				1	3	6																									6
Aoki	2011		9	10											8	3	4	5	6	7											1	2	11																					11
Sakano	2012																																	1	2																			2
Kondou	2013		3	4																	1										2	5																					5
E.Katalin	2013																																			1	2	3																3
H.Juan	2016		2	1					3																																													3
M.Colleen	2016																																						1	2															2
Kojima	2017	3		1																								2												4													4
F.Nicoleta	2019				1																												3									2	4	5	6	7	8	9	10	11				11
A.Diana	2019																																																		1			1
N.Evgeny	2019																																																		1		1
L.Andrea	2020								2																																												1	2
	Total	2	4	6	2	1	1	1	3	1	1	1	1	1	3	2	2	2	2	2	2	1	1	2	1	1	1	1	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	

1.Currency Value 2.Exchange Value 3.Use Value 4.Enterprise Value 5.Attributable independent Value 6.Attribution Value 7.Average Value 8.Market Value 9.Excess Value 10.Liabilities Value 11.Excess Value 12.Subsitution Value 13.Link Value 14.Customers Value 15.Brand Value 16.Basics Value 17.Convenience Value 18.Sense Value 19.Idea Value 20.Function Value 21.Functional Value 22.Emotional Value 23.Self-expression Value 24.Perception Value 25.Acquisition Value 26.Transaction Value 27.Semantic Value 28.Commodity Value 29.Attention Value 30.Assets Value 31.Experience Value 32.Context Value 33.Terminal Value 34.Instrumental Value 35.Consumption Value 36.Environment Value 37.Life Value 38.Money Value 39.Cultural Value 40.Means of Purchase Value 41.Props Value 42.Apparatus Value 43.CSR Value 44.Ethical Value 45.Personal Value 46.Ability Value 47.Payments Value 48.Knowledgeable Value 49.Ideal Value 50.Personality Value 51.Social Value 52.Intangible Value

3. Analysis methods

The analysis includes three steps. Step 1 is to investigate the tangible goods of this study, the music medium. The music media to be surveyed include television, radio, music programs, and music media. These will be surveyed using the Internet. Step 2 is to organize and discuss the relationship between the concept of value and music media. In chronological order, we will list the history of value and the music media in Step 1. As in Steps 2 and 3, the chronology will be colored by behavioral, psychological, and environmental periods, and the relationship between each period and each transition will be clarified. Step 3 will be a discussion based on previous research and Steps 1 and 2. Then, a discussion of the psychology of tangible purchasers in the intangible period will be conducted.

4. Research result

4.1 Surveying the history of the music medium (Step 1)

Comparing television, radio, and music media, television is the oldest medium. By the 1900s, radio had become so popular that sales of records, which were mainstream at the time, were one-fifteenth of what they had been at their peak. In 1940, the jukebox was born, and people were familiar with listening to music. The music medium changed from records to cassette tapes around 1960, and many music programs were broadcast in Japan at this time. The change in television to color TV also had something to do with the increase in singing programs. In the 1980s, CDs became the mainstream, and in the 2000s, digital devices such as iPods and distribution services such as iTunes and Recochoku (in Japanese) were promoted due to the influence of digitalization. In radio, listeners can listen to radio programs on their smartphones or PCs via the Internet. Services that allow users to listen to past programs, such as the time-free function, are also becoming more widespread. TVer (in Japanse), a service that allows viewers to catch up on missed episodes via the Internet, was launched in TV from 2015. In the music media, there is a trend to buy music over the Internet through subscriptions. Therefore, many Internet-based services have been offered since the 2000s.

4.2 Comparing the value concepts of each age group and music media (Step 2)

The music media of the 1980s and 1990s, the period of action, included records, cassettes, and CDs. The music medium has evolved with the times and technology, but

it is still tangible, so it can be said to be increasingly digitalized in a tangible form. This period includes the basic behavioral values: monetary value, exchange value, and use value. In the psychological period, 2000-2010s, playback devices such as radio cassette recorders and CD players were smaller and better designed than in the behavioral period. It is also a time of conversion from CDs to music distribution services, so we believe that the music medium is shifting from tangible to intangible and is changing into an attractive and convenient music medium. In the concept of value, many values that express a person's inner self have emerged, such as particular value, functional value, self-expression value, and brand value. During the environmental period from the late 2010s to the 2020s, music distribution services were mainstream and diversified, while sales of CDs, a tangible music medium, were stagnant. However, a core group of consumers who prefer CDs and records, which are now considered old-fashioned. The concept of value can be classified as intangible value, as it is a value that changes and adapts with changes in the environment. The ages are shown in Table 2, with blue for the behavioral period, pink for the psychological period, and yellow for the environmental period. For music media, the equipment that plays the media is indicated by a white circle (○), and the equipment that contains the sound source is indicated by a black circle (●).

5. Discussion (Step 3)

In the value of the action phase, the focus was on products and things, producing new things that were easy for people to use. In addition, a concept was defined for each value. We believe that after the psychological period, products were made from the perspective of invisible psychological aspects such as people's commitment and thoughts. Since the psychological part was added in the behavioral period, most values had concepts. In the environmental period, there were many papers that responded to the changing times, and most of the new values appeared, although some used values that appeared in the behavioral and psychological periods. In particular, the value named XX-like value is ambiguous in meaning and has no concept or definition. It was a term used to give meaning to a certain matter. In the behavioral period, the music medium has changed its form and performance about three times in 120 years from vinyl records to cassette tapes to CDs, and digitalization as a tangible form has been progressing. CDs were the predominant music medium from the 2000s during the psychological period, but from the early 2010s through the environmental period, digitalization transformed it into an invisible and intangible music medium. In the psychological period, there are many papers on brands and consumers, and brand value, which appears in many of them, expresses the psychology of people when they are involved with a branded product in

Table 2 Changes in value and music media

Era	Value	Music Media
1877		○Edison invents the "phonograph," an early phonograph.
1887		○The Gramophone, a disc phonograph, is born. ●Birth of the vinyl record.
1920		○Widespread use of radio.
1940		○The birth of the jukebox. ○●Commercialization of magnetic tape using the open-reel format.
1958		●The birth of the compacted cassette tape.
1964		●Compact cassettes are made the standard by Philips.
1978		○A small monaural type tape recorder is released by Sony.
1979		●Sony and Philips jointly developed a digital audio disc using laser beams (later to become the CD). ○Sony's stereo cassette player "Walkman No. 1" was born (with an ultra-lightweight headphone).
1981	Currency, Exchange, Use	
1982		●Launch of the compact disc (CD).
1984		○Sony introduces portable CD players.
1992		●Birth of the MiniDisc (MD).
1995	Corporate, Attributable Independent, Attributable, Average, Market, Excess, Liability, Excess, Replacement	
1996		●Birth of CD-R and MP3. ○Birth of the first MD Walkman from Sony.
1997	Link	
1999		○Birth of the CD Walkman from Sony.
2001		○Birth of the iPod. ●Launch of iTunes. Recochoku begins offering ringtones.
2003		○Birth of Network Walkman from Sony. ●Successfully sold songs on DL at iTunes Store.
2004	Customer, brand, basic, convenience, sensory, conceptual, functional, emotional, self-expression, acquisition, transaction, perception	
2005		○●Founded YouTube.
2006	Semantic, Product, Attention	
2007		○The advent of the iPhone.
2008		○●Spotify (music streaming service) is born. ○iPhone lands in Japan.
2009		○Sony created Walkman with digital audio technology.
2010		○●Started music distribution service for smartphones from Recochoku.
2011	Experience, Context	○●Google PlayMusic (unlimited music listening service) launched (~2020.12).
2012	Final, Means	
2013	Consumption, Environment, Life	
2014		○Sony presents the birth of the Walkman with high-resolution audio support. ○●Launch of LINE MUSIC (subscription music distribution service) and dHitz (unlimited music listening service).
2015		○●Started providing AWA (music distribution service).
2016	Financial, cultural	○●Launched Amazon Prime Music (unlimited music listening service).
2017	Means of Purchase	
2019	Instrumental, Instrumental, CSR, Moral, Personal, Competent, Additional, Intellectual, Ideal, Personality, Social	
2020	Intangible	○●YouTube Music (music streaming service) is launched.

terms of value. According to Wada (2002), brand value is defined in four categories: basic value, convenience value, sensory value, and conceptual value. On the other hand, Tanaka (2002) defines basic value, functional value, emotional value, and self-expressive value in addition to Wada's value. When looking at the music medium from the perspective of value concepts, we believe that self-expression value, convenience value, and sensory value are particularly relevant among the brand values. It also

assumes that these are the deep psychology of consumers when they choose tangible objects in the intangible age, and the relationship between these values is shown in Figure 2. From Figure 2, self-expressive value can be achieved by having the sound source itself, whether it is a CD, which is a tangible object, or an application, which is an intangible object, to satisfy oneself. In addition, Sony Walkman, a playback device, exists as a visible self-expression value in the music medium. By using the Walkman outside because of the changing functions of the playback device and having someone other than oneself see it, we believe that the self-expression value will improve and lead to self-satisfaction. Convenience value represents the convenience of consuming a product, so whether it is a CD or a digital one, you can use it in a way that is convenient for you. Even if a digitized object is generally considered easier and more convenient to use than a CD, the act of buying and using a CD is considered a convenience value for those who prefer to listen to music on a CD. Sensory value refers to the enjoyment and morphological appeal of a product when consumed. While it is possible to obtain sensory value from both CDs and digital media, we believe that CDs, which are tangible objects, have higher sensory value. In the modern age, CDs are the most tangible and mainstream music medium, and they allow people to enjoy the formal appeal of music. Even in the case of the tangible object, it is possible to enjoy the jacket and listen to the music on various playback devices, and this is a value. Therefore, we believe that the reason why CDs are still sold, and a certain number of buyers exist today, even though sales are declining, is because of the sensory value involved. From the lower level of sensory value to the middle level of convenience value in Figure 2, it is assumed that the product exists, and, the more tangible the product is, the higher the sensory value. As mentioned above, the concept of sensory value takes into account the attractiveness of a product in terms of form, which can take various forms, but in this case, it refers to visible form. Convenience value is the value of being able to use the attractiveness obtained from sense value as one pleases. Therefore, from sensory value in the lower tier to convenience value in the middle tier, the value is more product oriented. Next, from the convenience value in the middle tier to the self-expression value in the upper tier are values that are more psychologically oriented. These are the values that express the appeal and satisfaction of using the product at the lower level, and the convenience values exist from both the product and human perspectives. When considering CDs, the act of thinking and planning how to listen to a CD on a boom box, on a high-quality audio player, or on a display without listening to it is considered convenience value, and the execution of such planning is considered self-expression value. Based on the above, it can be considered that purchasing CDs, which are tangible objects in this age of digitalization and intangible objects, is an action that people take to satisfy themselves. Although there are various factors that may contribute to this, the basic values of the

behavioral period are based on the premise that the brand values discussed here, such as convenience value, sensory value, and self-expression value, respect the part of the psychological period that shows the inner self. In addition, they are thought to have thoughts that are not misled by the ideas of the environmental period, which indicates digitalization.

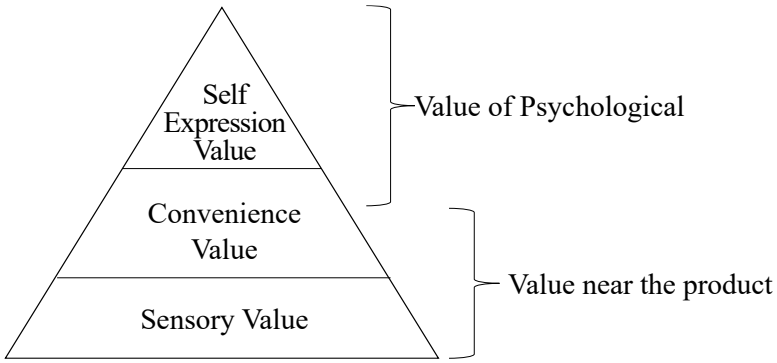

Figure 2 Deep psychology of tangible object choosers in the intangible era

6. Concluding Remarks

The study purposes to examine the psychology of consumers who choose tangible goods in this age of digitalization. As the result, this paper finds 52 kinds of values and interprets the music media using them. In the future, the study will develop the effective utilization system which involves their values for deeply reading and improving various social and economic activities.

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Innovation Enabled by Artificial Intelligence of Disaster Prevention and Disaster Relief Measures

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Abstract

Our paper discusses the development and application of energized AI unmanned vehicle in fireproofing、fire extermination, and fire relief. We analyze the unmanned vehicle with energized AI could drastically red ue the employee and labor cost with precise operation such that the overall potential benefit of fire prevention is huge. We could further develop the technology of AI energized unmanned vehicle by three stages of short、medium and long run. Finally, we propose some valuable suggestions about its future development and applications.

Keywords: Artificial Intelligence, Unmanned Vehicles, Intelligent Technology, Smart Applications

1、 introduction

Artificial intelligence technology can accelerate in the unmanned vehicle performing disaster prevention and disaster relief searching ability, data mining, machine translation, natural language processing, multimedia learning, voice dialogue and other related fields, which have achieved fruitful results with artificial intelligence technology to replace part of the manpower, which can reduce the burden of government budget spending and personnel tasks to maintain social security. Considering the current development of global science and technology and the emergency importance of disaster prevention and relief, and combining with the popularization of space positioning and searching technology in the future, the unmanned vehicle system should be regarded as an important accurate method of disaster prevention and relief.【1】

2、 The advantages of disaster prevention and relief

2-1. Reduce labor costs and casualties: due to the impact of fewer children birth, labor costs gradually increase and human resources gradually lack. If labor demand and costs are both

reduced by unmanned vehicles, the budget can be saved. Unmanned vehicles with radio control transmission, without man needed to drive, so for more dangerous tasks, which can be assigned by unmanned vehicles to reduce casualties, unmanned vehicles can go more deep into the disaster areas in a highly threatening environment to perform dangerous tasks without worrying about the loss of personnel life [2].

2-2. Great flexibility in use: Because unmanned vehicles have no personnel safety concerns, they can take a long time and find a wide range of investigation. Whether at night or in low visibility places, they can transmit the situation background observed on the scene in real time, and the information obtained will be more complete and correct. In addition, in a high-pressure and dangerous environment, unmanned vehicles can still correctly complete the delivery task without considering human psychological factors.

2-3. Low cost, disaster prevention and disaster relief benefits: unmanned vehicles need no drivers, so the original traditional vehicle for engineering and protection personnel system design can eliminate, which can reduce a large number of parts, the size of the vehicle can reduce somewhat, reducing the weight, improving the operation sensitivity, relatively improving the reliability and maintenance of unmanned flight vehicles, and reducing the dependence on logistics. In addition, because we need not worry about personnel physical and mental condition, so we can commit to the design of various vehicles with function excellence to make the existing disaster prevention and relief force by unmanned vehicles performing accurate guidance, which can maintain certain disaster prevention and disaster relief emergency ability by introducing artificial intelligence technology, by changing single-high-unit price to many-low-unit price with total system cost reduction, which can be small and cheap with micro drones group of disaster prevention and relief emergency to run and to solve the problem of limited budget and manpower shortage.

2-4. Effective support for disaster relief, elimination and prevention: Reliefing major disasters is an important task of the country. In terms of disaster prevention and rescue, unmanned vehicles can quickly enter the disaster areas and return the first-hand site information to the command center of the disaster areas because there exits the basic design [12] for the quick judgment and establishment of the response mechanism of the rescue personnel, as shown in Figure 1. After the disaster, the situation of the disaster area can be evaluated, and relevant recovery methods can be developed. For example, using unmanned vehicles to shoot two-dimensional images of the terrain and land, and then using IBM technology (Image Based Model) built 3 D model, which can be applied to serve disaster monitoring, typhoon flooding disaster monitoring, etc. In addition, when disasters occur, often accompanied by road and communication interruption, at this time, unmanned vehicles

can be loaded with wireless network devices to provide wireless network for the rescue of disaster areas.

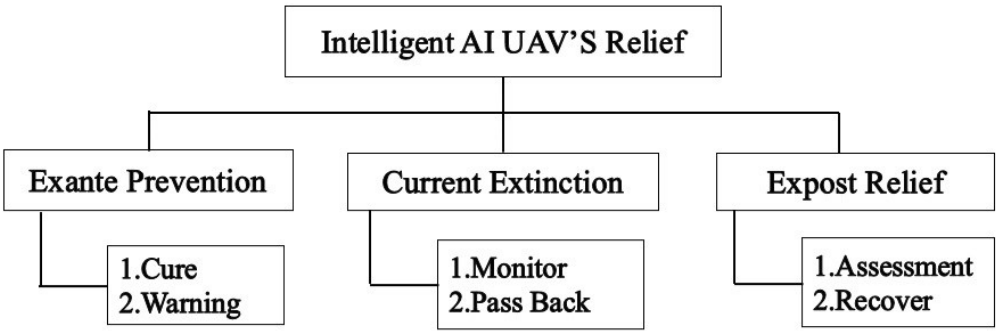

Figure 1 Relief program diagram for unmanned vehicle system support

2-5. Cross-strait cooperation and development: The AI technology needed for the unmanned vehicle cluster at this stage should be included in key industries in conjunction with the national promotion of the "Asia · Silicon Valley" plan. In terms of big data collection and mining, both sides have a strong information and communication technology ICT industry, There are also very strong Internet of Things (IOT) platforms, Integrating cross-strait semiconductor and electronic component manufacturing technology, Development of UCAV (Unmanned Combat Aerial Vehicle), HALE UAV (High-Altitude Long Endurance), MALE UAV (Medium-Altitude Long Endurance) to support the national disaster prevention and disaster relief measures [13].

3、 Self-control ability of an intelligent unmanned vehicle

In the actual environment of disaster relief tasks, unmanned vehicles are highly dynamic. Their disaster prevention situation and task objectives are constantly changing with time and environment, and require high sensitivity to time and environment, which makes the autonomous cooperative control of cluster unmanned vehicles become more important [20]. Artificial intelligence technology can effectively improve the autonomous control ability of unmanned vehicles.

The U. S. Department of Defense proposed the UAV System Roadmap [21] in 2005, which divided the unmanned vehicles into 10 levels, as shown in Table 1.

Table 1 Classification of autonomous control ability of unmanned vehicles

grade	name	description
10	Full autonomous cluster	Humans give little guidance to the work of unmanned vehicles, but they still have the highest authority.
9	Cluster has strategic objectives	Multiple unmanned vehicles, with little help, achieve strategic goals, but require human

		supervision.
8	Distributed control	There are no cores in multiple unmanned vehicles, using a distributed architecture, and multiple unmanned vehicle teams are performing tasks.
7	Cluster unmanned vehicle with tactical objectives	Among the multiple unmanned vehicles, there is a core vehicle responsible for tactical task assignment.
6	Cluster unmanned vehicle with Tactical heavy planning	Multi-vehicle response to sudden threat targets, sort and assign tasks to the targets and existing threats, and communicate information with other systems.
5	Cluster unmanned vehicle coordination	In the process of task execution, multiple unmanned vehicles can negotiate and make the best task decisions according to the status and task of each vehicle.
4	Vehicle path replanning	During the movement process, the unmanned vehicles can respond to environmental threats, replan their routes to avoid the threats, and can still complete the established tasks, with a certain intelligence.
3	Fault and attitude condition are adaptive	Unmanned vehicle can adapt to some faults and environmental changes, and can complete the established tasks.
2	Real-time fault diagnosis	Unmanned vehicle can complete the pre-compilation task, and can return the working status of the unmanned vehicle in real time.
1	Remote driving	The behavior of operating unmanned vehicles entirely driven and controlled by people.

Level 1 listed in Table 1 is typical of manual control, where unmanned vehicle depends on human remote control, simple gyroscope stability, no self-programming, no autonomous ability; Level 2,3, and 4 are typical of semi-automatic or automatic control, inertial navigation, satellite navigation technology, and rapid development of unmanned vehicle system at this stage can perform pre-programmed motion path, and later route replanning. Level 5 to level 10 is a typical ability of intelligent control with a variety of means of integrated navigation and learning control ability, unmanned vehicle at this stage can, according to the goal of human beings of automatically autonomous planning, perform tasks and prompt unmanned vehicle system to achieve fully autonomous goal, where the most key technology is the "artificial intelligence". According to the control level listed in Table 1 in the practice and the development process of technology, single unmanned vehicle intelligence is the basis, multi-vehicle collaborative intelligence is the way, and task autonomous intelligence is the development goal [22] which is planned for near, medium and remote targets, discussed as follows.

4、 Short-run near target

4-1, Single unmanned vehicle intelligence

Single unmanned vehicle intelligence refers to a highly dynamic and real-time mission environment. Unmanned vehicle can perceive the surrounding environment, avoid obstacles, be flexible, allow fault-tolerant flight, and independently plan the flight path according to the mission requirements. To achieve these capabilities, breakthroughs should be made in the following key technologies.

1) Intelligent perception and circumvention technology

Sense of related technical content includes： (a) design of reconnaissance, interference, detection, communication and integration; (b) multi-source / multi-mode information fusion processing technology; (c) location information sharing technology; (d) environmental adaptation technology; (e) new sensor technology. Making the moving unmanned vehicle which can sense the ability, can identify the obstacles in the action path, and accurately detour or pause, is an important step to achieve the intelligent unmanned vehicle, as shown in Figure 2. In the future, unmanned vehicle obstacle avoidance technology must be a breakthrough: deep camera obstacle avoidance technology, binocular visual obstacle avoidance technology, small electronic scanning radar, lightning scanning ranging radar, etc.

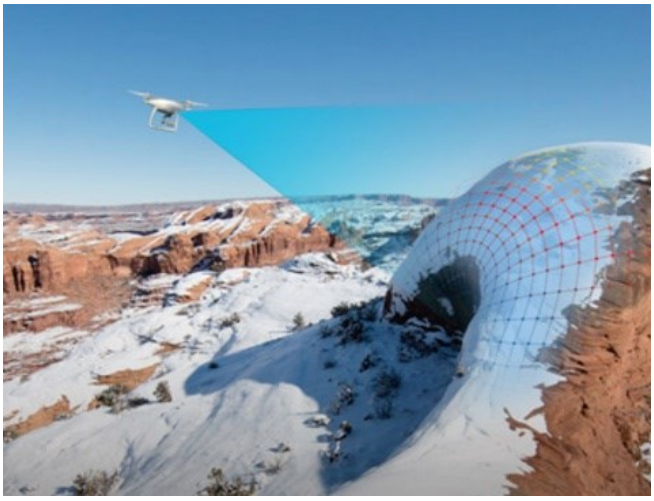

Figure 2 Obstacle detection and collision avoidance [23]

2) Intelligent path planning technology

Unmanned vehicle path trajectory planning, according to the needs of the task and real-time design from the starting point to the target point, pay the minimum cost to optimize the path trajectory. Action path planning must be constructed in accurate and clear positioning information, the positioning technology points out as follows: GPS carrier phase positioning, multiple source positioning, super broadband wireless positioning. However, in the actual disaster relief process, the site environment is very rapidly changing, and the changeable constraints have become the main focus. How to ensure the adaptability of the unmanned aerial vehicle mobile planning algorithm to the environmental changes and the real-time performance of the calculation is the technical focus of UAV.

3) Intelligent attitude control technology

Attitude control system is the core control device of the unmanned aerial vehicle, which is equivalent to the brain of the UAV. Whether it is equipped with posture control is also an important difference between the unmanned vehicle and the manned vehicle model. Its technologies include: (a) attitude stabilization technology, focusing on fault-tolerant and reconfigurable attitude control methods; (b) open attitude technology, focusing on the compatibility and scalability of attitude technology; (c) independent decision-making and fusion technology; and (d) self-learning and evolution technology.

4-2, Big data analysis technology and platform

Big data analysis platform mainly refers to new technologies such as new computing architecture and intelligent algorithm that process huge amounts of complex data, including: cloud computing platform for big data storage and management, machine learning algorithm for big data analysis and processing, etc. Under the multi-sensor, the data expression form has the diversities such as the huge data quantity, the complex relationship between data, the real-time requirements of data processing, and the fusion problem of heterogeneous multi-source sensors，which are discussed as follows：

1) Deep learning data analysis technology

Deep learning is one of the fields of machine learning research. Its core is to imitate the human brain mechanism, to establish an artificial neural network that simulates human brain analysis with learning, to explain the data such as image, sound and text, and to realize the mining of applicable features in big data and inductive learning [24] from data to knowledge. Major breakthrough in the field of deep learning masterpiece is AlphaGo, the experimental results confirmed that by utilizing deep learning technology, the robot can show similarity to human intuition image thinking and logical thinking ability with independent behavior and decision-making ability of intelligent machine of AlphaGo technology mode with the intelligent action, interactive design, task planning and command decision-making which has a significant impact.

2) Cloud computing technology

In essence, it is a distributed storage and computing mode of the network which is applied to the computing resources in the field of disaster relief, including: computing power and storage capacity [24]. At present, cloud computing has developed a series of new computing platforms and computing architectures such as MapReduce, Hadoop and Spark. In the future, big data analysis is mainly based on the perfect cloud computing capability, realizing the new unmanned vehicle disaster prevention and relief mode, and supporting the use of authorized equipment at any place and at any time.

3) Data and communication security

Problems with intelligent cloud computing include confidentiality, integrity and availability. Set strict requirements to prevent unauthorized disclosure of confidential data to ensure data and communications security. Users using the cloud computing architecture are critical to maintain the required level of security control when distributing and receiving messages to protect the message, and must retain its integrity and honesty to ensure that the data is not maliciously modified, and availability is the primary concern for users.

In recent years, quantum communication has attracted great attention. Due to the quantum inseparation and non-duplication characteristics which can achieve the purpose of quantum confidential communication, which is a very important technology for data and communication

security.

5、 Mid-run medium target

The key technology of Intermediate planning development of unmanned vehicle disaster prevention and disaster relief is to realize between unmanned vehicle system and human system to achieve automatic control "cluster" in the platform of unmanned system status, the collaborative execution between the formation and the disaster relief purpose. In the process of development,
it includes the following key technologies:

5-1, Communication technology of cluster UAVs

For the communication problem of the unmanned vehicle cluster, the unmanned vehicle can be regarded as the mobile communication network nodes with different network topologies and different communication performance. When the disaster prevention and relief of the unmanned vehicle clusters, the unmanned vehicle moves quickly. The positioning relationship between each UAV changes uncertainly, and the UAVs' fault or damage may occur at any time due to the interference of the disaster area. Therefore, the topology of the communication network of the unmanned vehicle cluster changes rapidly, the communication relationship between the unmanned vehicles is uncertain, unstable, and even may be interrupted at any time. These are the focus that the traditional wireless mobile network has not faced. To solve the above focus requires design in terms of network architecture, hardware, algorithms, and communication protocols.

5-2, Sensing and evaluation technology of cluster UAVs

Cluster perception refers to the unmanned carrier, based on the loading sensors, to obtain a wider observation range and higher positioning accuracy through the collaboration between the unmanned vehicles, and to realize the comprehensive perception of the disaster area environment, which is mainly for the collaborative detection of the external environment and the mutual perception ability within the cluster. Its technologies include: (a) collaborative state perception technology; (b) collaborative state processing technology; (c) collaborative state evaluation technology; and (d) collaborative state distribution technology. For example, collaborative state perception is environmental perception using sensors distributed on different UAVs.

5-3, Real-time task planning of cluster UAVs

4) tasking

In essence, unmanned vehicle clusters' task planning is a complex combinatorial optimization problem with many limitations. To achieve overall coordination and global optimization, the solution method of combinatorial optimization problem can be used to solve the task planning problem of unmanned vehicle cluster. The research should focus on solving the problem of unmanned vehicle cluster task planning, and must consider the real-time sensor information task planning timeliness and the speed of the task planning algorithm.

5) Real-time path planning

Under the premise of meeting certain limitations, such as its own mobility, safety height,

maximum distance, arrival time and the coordinated operation of other unmanned vehicles, it can be real-time planning and replanning toward the target direction with autonomous guide transmission.

5-4, Formation control of cluster UAVs

1) Establish formation arrangement

Multiple unmanned vehicles with independent task ability will be arranged in formation according to a certain geometric shape, so that their formation will remain unchanged in the process of movement. In the actual task implementation, multiple unmanned vehicles are formed in different formations to realize the complex tasks such as coordinated disaster prevention, disaster control and disaster relief. Reasonable and effective formation design can extend the movement distance of the unmanned vehicle formation, save fuel consumption, and increase the formation flexibility [25].

2) Formation split restructuring

Facing the sudden change of complex environment and tasks, on the basis of the single unmanned vehicle with intelligent path planning, it can be for unmanned vehicle formation with rapid and accurate adjustment, according to the collaborative content as soon as possible to quickly generate the performance of the optimal time formation.

Appropriate formation transformation scheme can improve the efficiency of fuel use and flexibly respond to emergencies, and realize the safe and rapid movement of the formation of the UAVs.

6、 Long-run remote target

How to seek methods to improve operational efficiency under limited human resources conditions is the problem that unmanned vehicle system users should try to solve [22]. Improving processing power and message storage capacity, especially airborne pre-processing capacity, are potential solutions to change how unmanned vehicle systems operate. Autonomous technology reduces the workload of people in the operating system, optimizes the role of people in the system, and concentrates people's decisions where they are most needed. Therefore, the development of task-autonomous intelligence includes the development and application of the following key technologies:

6-1, Pattern recognition technology for speech, text, and images

Artificial intelligence, including image recognition algorithms and speech and semantic recognition algorithms, through these pattern recognition technologies, they can help unmanned vehicles to improve to control navigation and path planning drawing and other functions, and to achieve fully autonomous goals. Pattern recognition refers to the process of processing and analyzing various forms of information of characteristic things or phenomena, such as speech, text and images, to describe, identify, classify and explain things or phenomena. Pattern recognition is a basic human skill. For example, whether it is a complete apple, cut through a partial apple, or a chopped apple, humans can quickly make the right judgment based on their characteristics. The ultimate goal of the human brain is how to transform the thinking pattern of determining "Apple" into a reliable algorithm that can be implemented by the calculator,

which is the ultimate goal of pattern recognition technology.

6-2. Distributed autonomous task planning technology of cluster UAVs

Multi-agent autonomous decision-making technology can be regarded as a combination of distributed computing and artificial intelligence, mainly in how to emerge the overall behavior through the dynamic response to the environment and the simple coordination between the multiple individuals. In many literature, agents are usually used to represent individuals in biological group systems, so the multi-agent theory can also be called the group system theory. Agents can be motion units such as unmanned vehicles, ground mobile robots, or wireless sensor nodes. Due to the multi-agent theory, it belongs to the distributed operation mode, which has no center control node, local information exchange and simple behavior coordination characteristics, so that the main problem decomposition, subproblem modeling, subproblem solution, and subproblem coordination solution process, which can effectively reduce the autonomous collaborative control problem to solve difficulty and complexity of the UAVs[20].

7、 Conclusion: The development of intelligent UAVs is suggested

Small and unmanned vehicle system can be used as an asymmetric disaster prevention and disaster relief method. Current tactical-level unmanned vehicle technology has a relatively low entry barrier. There are some famous units to participate in the research and application of hardware and software systems of UAVs, such as: Lei Hu, Jingwei Company, Industrial Institute, Metal Industry Research Center, Chinese Academy of Sciences, top universities and research centers, etc.. Its basic research and development capabilities and some key technologies have been complete, where the reserving technical energy of each unit should be integrated, and establishing a cross-domain integration platform in a systematic research and development way to strengthen the scientific research strength of disaster prevention and control and emergency rescue of unmanned vehicles. There must be a great success.

In addition, there are the following five suggestions to pay attention to develop the artificial intelligence enabled UAVs : 1, confirm the future emergency rescue requirements for disaster prevention. 2, organize the emergency rescue project team. 3, integrate the academic energy of emergency rescue. 4, promote the defense industry of emergency rescue. and 5, cultivate the interdisciplinary and professional emergency rescue talents.

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A Proposed Methodology of Augmented Intelligence for TRIZ Contradiction Analysis

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Abstract

The traditional TRIZ contradiction analysis is processed entirely by users to identify a problem and select the related engineering parameters. Because of different individual viewpoints on the problem, it may lead to the divergence of contradiction analysis and problem solving. Therefore, this study proposes to introduce "Augmented Intelligence" to assist users in making up for the negative effects caused by personal subjective judgment and psychological inertia in the process. Using the 48 engineering parameters proposed by Darrell Mann, we intend to develop the guiding procedure and mechanism for identifying contradiction problems, and define the possible positive and negative directions of engineering parameters based on the keywords of required functions. Applying Natural Language Processing (NLP) techniques, we propose to import the patent database for model training, then search and compare patent texts with high correlation with engineering parameters. Through semantic analysis of patent documents to help define improving engineering parameters and worsening engineering parameters, so that contradiction analysis can be more consistent in use, then facilitate further problem solving.

Keywords: TRIZ, Contradiction Analysis, NLP, Patent Mining

1. Introduction

Due to the global pandemic of COVID-19, which has had an indelible impact on various industries around the world. Because of this crisis, TRIZ theory has an opportunity to develop at the level of innovation and problem solving (Mann & Rashid, 2020). With the rapid development of science and technology today, the application of artificial intelligence in life is becoming more and more extensive. It can not only be used as a leading tool in the well-known smart home level, but also as a supporting tool in many research fields. It is used to help determine the semantics of the text, so as to reduce the thinking inertia and logical mistake that may occur in the process of human judgement. AI is just a tool or medium, however the most important thing is "human". Thomas Friedman, a three-time Pulitzer Prize winner, once pointed out in his speech that "AI (Artificial Intelligence) should be

reversed into IA, and use of Intelligence Aids, Intelligence Assistance and the role of Intelligence Algorithm". Therefore, the concept of "Intelligence Augmentation (IA)" or "New AI (Augmented Intelligence)" was born. Augmented intelligence is defined by Gartner as a collaborative model in which humans and AI work together to improve cognitive performance in a human-centered manner. Through this man-machine collaboration, better results can be achieved than either side "working alone". AI is aimed at leading, but IA is aimed at assisting with humans as the main body, using IA for auxiliary judgment. This research is based on this concept as the framework to deal with the issue in how to combine IA technology with text analysis applications.

▪1.1 Motivation

This research is based on the 48 engineering parameters and contradiction analysis proposed by Darrell Mann. Although the existence of contradictions is an obstacle to problems solving, it can also be an opportunity for breakthrough progress. The common application of TRIZ theory in problems solving is to first find out the contradiction. The traditional TRIZ technical contradiction analysis method is to analyze and summarize the system characteristics that often encounter conflicts from 48 engineering parameters, and organize them into a matrix table. The 40 invention principles within the table are then applied for solving the contradiction problems based on the improving parameter and worsening parameter. Such solving the contradiction phenomenon is the future application trend of TRIZ innovation. However, the uncertain factors existing in the practical application of traditional TRIZ contradiction analysis are mostly based on human judgment currently. If the complexity of the technical system problems increases, the engineering parameters involved may also increase as well, which will lead to inefficiency of contradiction analysis to solve problems.

Montecchi and Russo (2015) described how to use information extracted from patent literature to innovate products to identify and overcome TRIZ contradiction. In this paper, an algorithm is proposed to guide the user from uncertain problem situation to obtain a clearer problem representation. It follows the process of solving physical contradictions inspired by ARIZ method to obtain the necessary information for the final modeling, so as to improve the effectiveness of the contradiction model. However, to improve problem solving efficiency, Intelligence Augmentation should be introduced into the process of problem solving.

▪1.2 Purpose of Research

A major subject of this research is to develop a guiding process for identifying contradiction, defining contradiction and finding out the engineering parameters of contradiction with the assistance of AI. This research will focus on two core topics: "Definition process of contradiction" and "using AI-assisted Labeling of engineering parameters in Patent Texts", using text mining technology through “Natural Language Processing (NLP)” to conduct related research of Intelligence Augmentation (IA). It can be used to identify the improving and worsening parameters of the contradiction matrix, and help the user to screen the engineering parameters more efficiently and effectively.

2. Literature Reviews

▪2.1 TRIZ Contradiction Analysis

TRIZ's approach to problem-solving involves eliminating contradictions in the problem. The contradiction classification of TRIZ is divided into “Technical Contradiction” and “Physical Contradiction”. The following definitions and descriptions of these two contradiction types will be given:

(1) Technical Contradiction: When attempts to improve some attributes or functions of the system lead to the deterioration of other attributes of the system, technical contradiction will occur, which is the conflict between two parameters (Ilevbare, Probert, & Phaal, 2013).

For example: If you want to improve the light bulb, how to save electricity without dimming? The contradiction is to improve the energy consumption, but it will make the brightness worse. Therefore, first find the worsening parameter "18. Illumination intensity/Brightness" of the 48 engineering parameters from the horizontal axis of the table, and then find the improving parameter "20. Use of energy by stationary object" from the vertical axis of the table. Use the columns and rows to compare the values 19, 2, 35, and 32 in the table. The values represent the principles in the 40 invention principles: "19. Periodic action", "2. Taking out", "35. Parameter changes", "32. Color changes". The methods and approaches suggested by the values in the grid can provide designers with new thinking directions and principles to carry out the design of inventions and improvements, as shown in Table 1.

Table 1. Instructions for using the contradiction matrix table

Improving parameter \ Worsening parameter		1	...	18	...
		Weight of moving object	...	Illumination intensity/Brightness	
1	Weight of moving object		...		
⋮	⋮				
20	Use of energy by stationary object			19, 2, 35, 32	
⋮	⋮		...		

Suggested workaround

19. Periodic action
2. Taking out
35. Parameter changes
32. Color changes

(2) Physical Contradiction: When there are inconsistent requirements for the physical conditions of the same system, physical contradiction will occur, which is the conflict of single parameter

itself. A system may have a function or be in a state that is both favorable, unfavorable or unpleasant. For example, in order to use chopsticks more easily, the length of chopsticks should be increased; On the contrast, in order to facilitate portability, the length of the chopsticks should be shortened. This is the physical contradiction of the parameter "Stationary Length". Physical Contradiction may be removed by separating two conflicting requirements using four separation principles, including: "In Space", "In Time", "On Condition", and "By transition to an alternative system" (Mann, 2002).

▪2.2 Forty-Eight Engineering Parameters

Altshuller proposed 39 system characteristics, which are usually associated with one type of contradiction, and then classified the engineering problems into 39 engineering parameters, divided into six categories: geometry, resource, harm, physics, capability, and manipulation. Matrix 2003 was proposed by D. Mann in 2003, aiming at parameters that were not sufficiently resolved in the original matrix, and extending the engineering parameters to 48 in order to reorder the parameters into a more logical and informative sequence (Mann & Dewulf, 2003), and reclassified into six categories, "Physical/Geometrical parameters", "Performance parameters", "Efficiency parameters", "Capability parameters", "Manufacturing/Cost Reduction parameters" and "Measurement parameters". The new parameters include: 11.Amount of information, 24.Function efficiency, 29.Noise, 30.Harmful emissions, 33.Compatibility/Connectivity, 37.Security, 38.Safety/Vulnerability, 39. Aesthetics/Appearance and 46.Control Complexity, as shown in Table 2 (Mann, 2009).

Table 2. 48 engineering parameters of Matrix2003

1. Weight of moving object	2. Weight of stationary object	3. Length/Angle of moving object	4. Length/Angle of stationary object
5. Area of moving object	6. Area of stationary object	7. Volume of moving object	8. Volume of stationary object
9. Shape	10. Amount of substance	11. Amount of information	12. Duration of action of moving object
13. Duration of action of stationary object	14. Speed	15. Force/torque	16. Energy used by moving object
17. Energy used by stationary object	18. Power	19. Stress/pressure	20. Strength
21. Stability	22. Temperature	23. Illumination intensity	24. Function efficiency
25. Loss of substance	26. Loss of time	27. Loss of energy	28. Loss of information
29. Noise	30. Harmful emissions	31. Other harmful effects generated by system	32.Adaptability/versatility
33.Compatibility/connectability	34. Ease of operation	35.Reliability/robustness	36. Repairability
37. Security	38.Safety/vulnerability	39. Aesthetics/appearance	40. Other Harmful Effects Acting on the System

41. Manufacturability	42. Manufacture Precision/Consistency	43. Automation	44. Productivity
45. System Complexity	46. Control Complexity	47. Ability to Detect/Measure	48. Measurement Precision

▪2.3 Patent Mining

The patent layout can be divided into strategic patent layout and technical patent layout. Technical Patent layout is often referred to as "Patent Mining", which means to further change some of the working principles or components of the existing patent technology through systematic analysis, and then extend and develop the existing patent technology, so as to explore more possible patents. Tseng, Lin, and Lin (2007) proposed to automate the process of patent analysis techniques, such as text segmentation, abstract extraction, feature selection, term association, cluster generation, topic recognition and information mapping, and apply them to actual patent sets to help create the final patent map for topic analysis. It also helps to improve other patent analysis tasks, such as patent classification, organization, knowledge sharing, and prior art search. Yu-Hsiu Tai (2021) proposed to cut patent documents into paragraph level as a solution to solve BERT input length limitation. The vector representation of each patent document paragraph is calculated through the Sentence-BERT pre-training model, and semantic-based patent retrieval is performed by comparing the similarity between patent vectors.

▪2.4 SAO Structural Analysis

SAO structural analysis is a structure based on the Subject (noun phrase), Action (verb phrase) and Object (noun phrase). It is usually used to represent technical functions and can clearly deconstruct the relationships among functions, effects, solutions, technical concepts and components that appear in patent texts (Cascini, Fantechi, & Spinicci, 2004). Through the Subject (node) – Action (edge) – Object (node) links to investigate the relationship between actors. It also uses structural holes, changes in the distribution of node degrees, and shifts in network centrality to detect trends in technology development. The main function is to analyze keywords in sentences (Yang, Huang, & Su, 2018). In the latest SAO structure, the S-A-O word network is formed, which establishes a broader and more precise basis for judging the degree of association between the subject (S), verb (A) and object (O).

Objects, tools, methods, and systems of the inventions specified in the patent can be expressed in the form of Subject (S) in a sentence that contains a description of the technology. For example, in the sentence, "Nanosensor detects micro-signal" is composed of Subject ("Nanosensor"), Action ("detects") and Object ("micro-signal"); "Nanosensor" represents the solution or tool described in this technical sentence, and "detect micro-signal" clearly means the function that the "nanosensor" performs. In addition, if subject and object are components or subsystems of a technical system, the action included in that sentence may represent the structural relationship between the components. For example, in the sentence, "Nanosensor includes carbon reactor", "Nanosensor" and "carbon reactor"

mean the components described in this technical sentence and "includes" can mean a structural and partitive relationship. A SAO structure can also represent a problem-solution relationship, in which the subject represents a solution and AO represents a required function or problem(Ki & Kim, 2017).

▪2.5 Natural Language Processing

Natural Language Processing (NLP) is a branch of artificial intelligence and linguistics that explores how to process and use natural language; It includes many aspects and steps, including cognition, understanding, generation and so on. It combines linguistics, information science, artificial intelligence and other disciplines, it assists machines to judge the semantic and sentence structure of natural languages from the characteristics of sentences, so as to conduct preliminary deconstruction and analysis of unstructured documents (Song, 2017). Related application technologies include (Chen, 2021): Bags of Words (BOW), TF-IDF (Term Frequency-Inverse Document Frequency), Word preprocessing (NLTK), Word2Vec, GloVe (Global Vectors), Chinese processing and spaCy kits. Recently, NLP is widely combined with deep learning. The most famous one is BERT (Bidirectional Encoder Representations from Transformers), which is the model developed by google based on the Transformers suite.

▪2.5.1 BERT Model

BERT (Bidirectional Encoder Representations from Transformers) is the pre-training technique for natural language processing (NLP). It is a bidirectional language representation model that Google makes use of a large amount of unlabeled text in an unsupervised manner. Developers pre-trained models on the 800 million words book corpus and the 25 million words English Wikipedia. The architecture is the Encoder in the Transformers suite, which is a deep bidirectional and unsupervised language representation and only uses pure text corpus for pre-training model (Devlin, Chang, Lee, & Toutanova, 2018). Most of the pre-training models in the past are context-free models, such as Word2Vec or GloVe, which generate a word vector for each word in the vocabulary, so word ambiguity is prone to occur. BERT considers the context in which a word appears and provides different word vectors according to the context, which is related to the meaning of the sentence. The model training of BERT is divided into two stages: "General model training" and "Fine-tuning" based on different application fields. Then, the pre-trained model is connected with a customized fully connected layer to meet the requirements of each application field. Two training strategies are followed during training, namely "Masked Language Model (MLM)" and the "Next Sentence Prediction (NSP)" to minimize the combined loss function of the two strategies (Meng, 2019). The functions of fine-tuning are mainly divided into three categories: Classification, Question Answering, and Named Entity Recognition (NER).

▪2.5.2 Sentence-BERT Model

The architecture of Sentence-BERT network improves the basic model training method of BERT. Use siamese and triplet network structures, they are "[CLS] vector strategy", "Average Pooling strategy" and "Max Pooling strategy". By inputting different sentences into two BERT models, the representation vector of each sentence is obtained, and then the cosine-similarity is used to calculate the semantic similarity, which can also be used in unsupervised clustering tasks (Reimers & Gurevych, 2019). When fine-tuning the model, three objective functions are set, namely "Classification Objective Function", "Regression Objective Function" and "Triplet Objective Function" to optimize different training tasks.

3. Methodology

This research method starts from the "Problem Definition Process", importing the "Patent Database" for searching, statistics, classification, comparison, etc., to filter out the patent documents related to the characteristics or attributes of the contradiction problems. Then, by comparing the characteristic keywords extracted from it with the expansion word database of engineering parameter, the relevant engineering parameters may be found, and the characteristic patent group is screened out, so as to provide improving parameters and worsening parameters that are highly related to the requirement. The flowchart is shown in Figure 1. The details are described as follows.

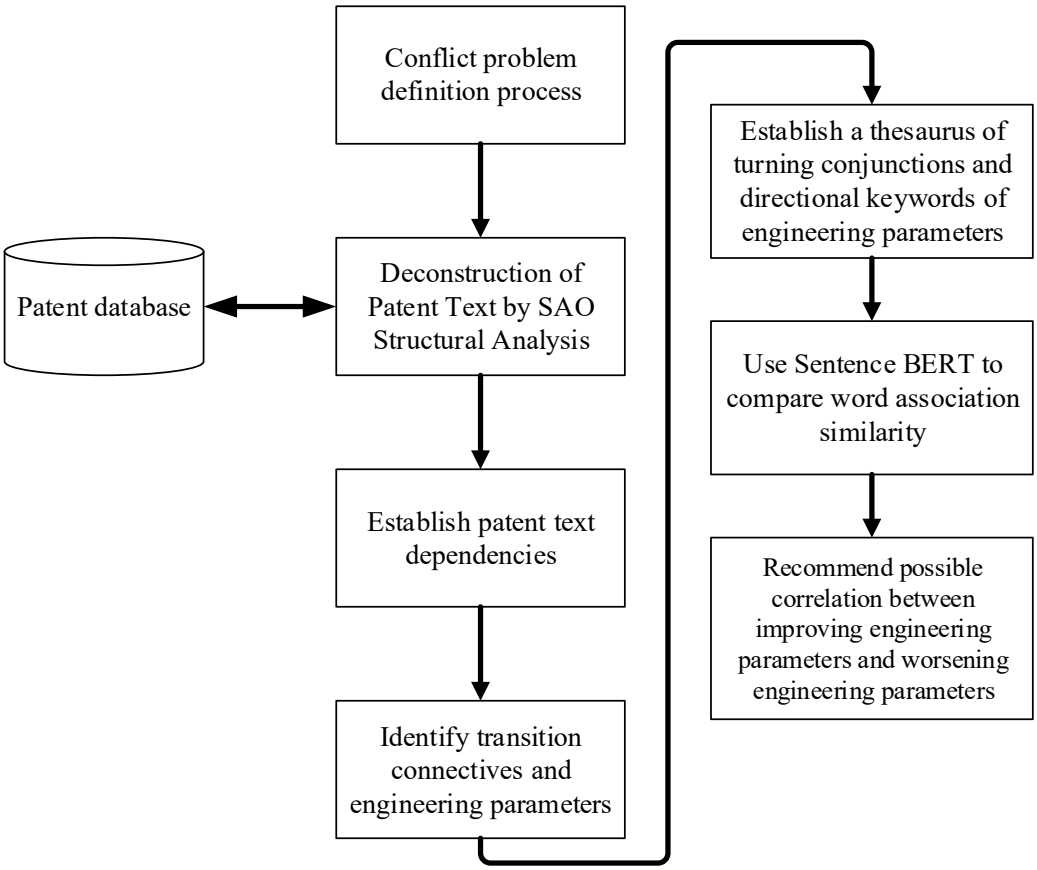

Figure 1. Import patent database to identify engineering parameters of contradiction

▪3.1 Definition of Contradiction Problem

Through the problem definition of "Desire to Achieve", we enter the problem-solving process of finding the contradiction point. In the traditional process of contradiction identification by human, sometimes the contradiction point cannot be clearly identified because the benefit of a technical system is not clear. Therefore, this study will establish the guiding steps and processes for identifying contradiction problems and assist in finding the problem points.

▪3.2 Import Patent Database for Semantic Analysis of SAO Structure

In order to find out the transition words mentioned in the patent document, when performing the bag-of-words (BOW) for the patent or using NLTK suite for word sorting, in the steps of word segmentation, pre-processing, removal of stop words, number of word occurrences, etc., keep some specific transition words in stop words, so that the dependency parsing in SAO structure can be used to find the correlation value between words. The process after importing the patent database is shown in FIG. 1. After the above guiding process of defining contradictions, then import the patent database as an example, make the patent go through the definition process of the contradiction, use the SAO structure analysis and the patent text dependency parsing to find the transition words and the engineering parameters before and after it. Establish a transition words and engineering parameter directional keywords, then use Sentence-BERT to compare the correlation similarity. Finally, the most relevant improving engineering parameter and worsening engineering parameter are found.

▪3.2.1 SAO Structural Semantic Analysis

Using preprocessed SAO structures to build the network, the extracted SAO structures with the corresponding patent document can be expressed as: $P_x = [(S_1, A_1, O_1), (S_2, A_2, O_2), \ldots, (S_n, A_n, O_n)]$, where P_x is patent document x, while (S_n, A_n, O_n) represents the subject, action, and object of the SAO structure. These SAOs are presented in a (Subject, Action, Object) format. By calculating the strength of relationship between Subject Node and Object Node, all the subject nodes and object nodes are connected with the action based on the (Subject, Action, Object) set to generate an SAO structural network (Yang et al., 2018). By cutting the patent text into SAO structure representation, it can greatly help the subsequent use of dependency parsing.

▪3.2.2 Dependency Parsing Analysis of Patent Documents Based on SAO Structure

Dependency Parsing (DP), first proposed by the French linguist L. Tuesniere, is an important stage in NLP. It focuses on identifying the correlation between words in a sentence. The correlation is called Dependency, and the structure is characterized by a binary form consisting of two words. The advantage is that the subject, verb, and object are presented in different ways and in different orders, which can effectively find the dependencies between words (Hsieh, 2021).

Since most machines have certain characteristics related to general technical equipment, such as the wingspan of a water jet as an example (Altshuller, Shulyak, & Rodman, 1999): To build a frame up to three meters in length, its overall weight would increase, the wingspan would be tripled due to the structure, and its supporting frame would be 27 times heavier than before. From this example, we can see that there will be some interdependence between the characteristics of some equipment, such as weight, size, power and reliability, which will jointly indicate their degree of efficiency, such as: A unit of power requires a certain weight of structure. Therefore, in order to find out the engineering parameters in a problem description, it is necessary to find out the interdependence between the words.

Dependency Parsing are divided into three categories: “Clausal Argument Relations”, “Nominal Modifier Relations” and “Other Notable Relations”. The details include “Nominal subject (nsubj)”, “Direct object (dobj)”, “Indirect object (iobj)”, “Clausal complement (ccomp)”, “Open clausal complement (xcomp)”, ... and other 37 species, some categories are excerpted in Table 3.

Table 3. Category of Dependency (De Marneffe et al., 2014)

Clausal Argument Relations	**Description**
Nsubj	Nominal subject
Dobj	Direct object
Iobj	Indirect object
Ccomp	Clausal complement
Xcomp	Open clausal complement
Nominal Modifier Relations	**Description**
Nmod	Nominal modifier
Amod	Adjectival modifier
Nummod	Numeric modifier
Appos	Appositional modifier
Prep	Prepositional modifier
Case	Prepositions, postpositions and other case marks
Other Notable Relations	**Description**
Conj	Conjunct
Cc	Coordinating conjunction

Dependency parsing is mainly divided into “Clausal Argument Relations” and “Nominal Modifier Relations”. The dependent clause relation is usually related to the predicate, which also represents the main semantic meaning in the sentence, and usually may be a verb, called ROOT.

Modifier relations are classified to modify subjects (Lee, 2019). From Figure 2, it can be clearly understood that all the arrows of the word "jumped" are facing outward, which is called ROOT, and ROOT cannot be pointed by any arrow. Taking "jumped" as the starting point to find nsubj, the corresponding word is "fox", and "fox" is the main word, which is a “Clausal Argument Relations”. Another word corresponding to prep is "over" and "with", "over" and "with" are preposition modifiers, which are “Nominal Modifier Relations”.

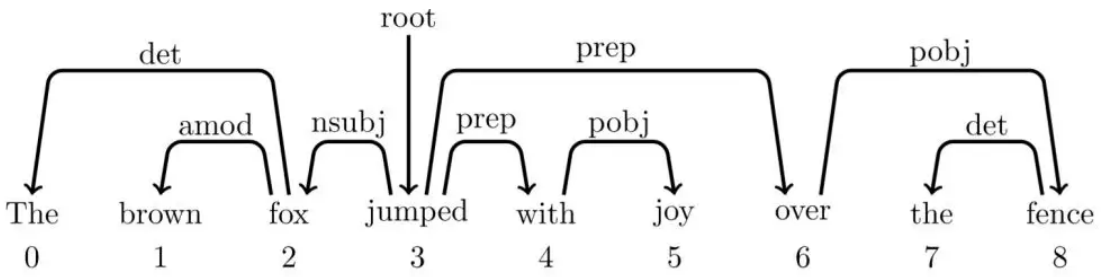

Figure 2. Examples of Dependency Parsing

▪3.2.3 Identifying Contradiction Problems and Engineering Parameters by Dependency Parsing

Using SAO structural analysis method to identify contradictions in patent background. Enter “bicycle” from the United States Patent and Trademark Office (USPTO) for retrieval. Taking the patent ID US 20220219727 A1 as an example, “path planning system-however-inefficient”, the subject (S) “path planning system” and the object (O) “inefficient” can be regarded as two elements, and the transition word “however” is taken as the structural relevance (A) between them to form the structural form of SAO.

With the use of contradiction problem definition process. Combined with the patent background context and the establishment of the transition words dictionary. Comparing the values of the correlation degree of the two engineering parameters in the context of the transition words can form a mechanism to assist in judging the improving engineering parameters and the worsening engineering parameters in the description of the contradiction problem.

▪3.3 Transition words and Engineering Parameter directional dictionary

Since a patent is developed with a description of the developer's requirements or improvements to the patented product in the background field. When describing requirements, some transition conjunctions words are often used, such as “but”, “however”, “because”, etc. Before and after these words, there will be the problems he encountered when developing the patent and the situation he wants to improve. Therefore, if the problem description can be used to help users find the improving engineering parameters and worsening engineering parameters that meet their needs through the transition words used by users in the contradiction of the problem requirement description. Enter

"bicycle" from the USPTO to search, taking patent No. US 20220219727 A1 as an example, some background descriptions of this patent are excerpted as an illustration:

Original Text: *A vehicle such as an autonomous vehicle will utilize a path planning system to identify a path which the vehicle may navigate through an environment. In legacy systems, this path planning system uses a sampling-based approach to identify the path. However, this sampling-based approach may be inefficient, or may encounter inefficiencies in situations where the velocity of the vehicle is very low or approaching zero.*

In the background description of the patent, the transition conjunctions word "However" is used, and the information about the need to improve functionality mentioned before the transition word, "using the path planning system to identify the best navigation path", is noted in the description. The engineering parameter "11. Amount of information" can be regarded as its improving engineering parameter. After the transition word, the problem of low efficiency is mentioned, and this description can correspond to the engineering parameter "24. Function efficiency" as its corresponding worsening engineering parameter.

▪3.3.1 Transition conjunctions keyword dictionary

"Turning" is the meaning of changing from one theme to another, and can be expressed by transition words or phrases, they are often placed at the beginning of sentences, in separate clauses and in paragraphs to create links between different themes and ideas. The classification of Transition Words in usage can be divided into four main categories (Transition Words, 2020): "Additive transitions", "Adversative transitions", "Causal transitions" and "Sequential transitions". In terms of identifying contradictions in problem description, it is easier to use "Adversative transitions" and "Causal transitions" according to the way the public describes problems, as shown in Table 4. This study will conduct in-depth discussion on these two categories.

Table 4. Category of Transition Words

	Category	Synonym / Similar words
Transition words	Adversative transitions	but, however, while, whereas, nevertheless, although, though, etc.
	Causal transitions	since, due to, because, owing to, if…then, therefore, thus, so as to, in order to, etc.

The usage of transition conjunctions:

(1) {A} + {Causal transitions} + {B}

For example: {Worsening Engineering Parameters} + {so, therefore…} + {Improving Engineering Parameters}.

(2) {C} + {Adversative transitions} +{D}

For example: {Improving Engineering Parameters} + {but, however…} + (Worsening Engineering Parameters).

Taking "engineering equipment" as the keyword, the patents searched on the USPTO, extracting part of the background description of the patent NO. US 20220223305 A1 as an example:

Original Texts: *The heat exchange area of a narrow slit channel is large, boiling is generated more easily, bubbles are formed and circularly flow in the loop, large flow resistance is brought, and meanwhile, the flow and heat transfer characteristics of the coolant in the loop are further changed. Therefore, it is very necessary and important to carry out experimental research on the dynamic characteristics of narrow slit channel bubbles under an ocean motion condition.*

Before the causal transition word "therefore", describe the current situation of its engineering equipment that needs to be improved, such as "flow resistance", which can correspond to engineering parameters "14. Speed" and "19. Stress/pressure" as worsening engineering parameters; After the "therefore", it is explained that its need to improve the goal, such as a better understanding of the characteristics of bubble dynamics, can correspond to the engineering parameters "11. Amount of information" as its improving engineering parameters.

In addition to the transition words, the verb of the key word is also prone to be used to distinguish between improving engineering parameters and worsening engineering parameters.

(1). Positive words: in order to, to achieve, preferable, better, best, enable, easily, necessary, etc.

(2). Negative words: lead to, cause, bring about, result, fail to, etc.

For example, using "screw wrench" as the keyword to conduct a patent search, take the background description of the excerpt from the patent NO. US 20220221022 A1 as an example:

Original Texts: *To achieve a minimum preload force, a large safety factor must therefore be taken into account, which also leads to a large damper rod diameter.*

It can be seen from the above example that after the use of the positive word "to achieve", the description of the improving parameter "minimum preload force" will be added, which can correspond to the engineering parameter "21. Stability"; After the negative word "lead to" is used, the description of "larger diameter of the damping rod" will be followed, which can correspond to the engineering parameter "4. Length/Angle of stationary object" as the worsening engineering parameter.

By marking the transition conjunctions words and positive and negative sentences in a problem description, it will help to identify the engineering parameters mentioned in it.

▪3.3.2 Dictionary of Engineering Parameter directionality

After successfully finding the problem point, the corresponding improving engineering parameters and worsening engineering parameters are also different due to the different perspectives of users for the problem. The invention principle found by the contradiction matrix table will be affected by the difference between the improving parameters and the worsening parameters. Therefore, it is important to select the engineering parameters that are more suitable for the contradiction problem itself. In this study, the characteristics of engineering parameters, such as worsening parameters and improving parameters, are used to add positive and negative signs to their change characteristics, such as "increase" or "decrease". In addition to further extracting the characteristics of the patent, it can also be used as a reference for judging the improving parameters and worsening parameters. As shown in Table 5, taking the engineering parameter "14. Speed" as an example, increase or decrease as a keyword field, which is called "direction" and indicates positive (+) and negative (-) signs.

Table 5. Characteristic Definition of Engineering Parameters and their directionality (take Speed as an example)

NO	Engineering Parameter	Positive (+)	Negative (-)
14	Speed	increase	decrease
		better	reduce
		higher	lower

By marking the directionality on the parameter, it is easier to find out where the engineering parameter is in the patent description, and it is easier to identify whether the parameter is an improving parameter or a worsening parameter.

▪3.4 Sentence-BERT sentence vector and cosine similarity comparison

Through the above steps, a positive and negative dictionary of engineering parameters is generated, so that it can be input into the BERT model as training data for similarity comparison. Different from the model training application of standard BERT, Reimers and Gurevych (2019) developed the Sentence-BERT model and improved RoBERTa proposed by Liu et al. (2019). It is not necessary to input two sentences to train the model, but to derive the semantically meaningful sentence embedding vector using the siamese and triplet network structures, and then to compare the correlation similarity through the cosine similarity.

▪3.4.1 Generating Sentence Vectors Using Sentence-BERT

SBERT set three objective functions when fine-tuning the model. They are "Classification Objective Function", "Regression Objective Function" and "Triplet Objective Function". The ultimate goal is to obtain the embedding vector of the sentence.

(1). Classification Objective Function: It is used for classification tasks, such as judging the similarity between two input sentences to see if they can be classified into the same label, as shown in Figure 3. Input two sentences and obtain the vector representation of the two sentences as u and v respectively through pooling strategy. Form a new vector by the absolute value of the difference between u, v and vectors, and multiply it by the weight parameter $W_t \in R^{3n*k}$, where n is the vector dimension and k is the number of classification labels. Finally, the similarity probability is obtained through Softmax function. $o = \text{softmax}(W_t (u, v, ||u - v))$.

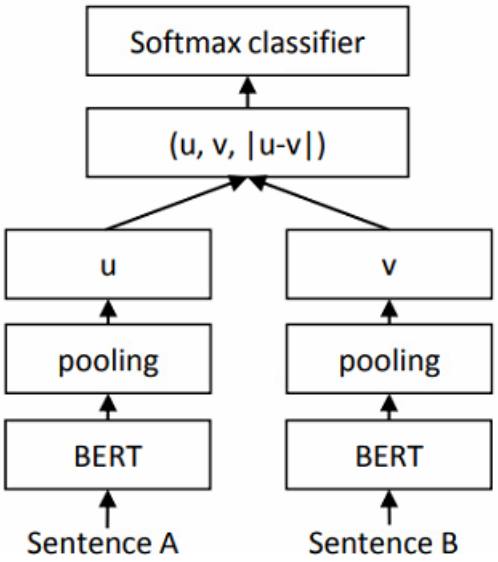

Figure 3. Sentence-BERT Classification Objective Function architecture flowchart

(2). Regression Objective Function: Calculate the cosine similarity value between two sentence embedding vectors u and v. The process is shown in Figure 4, and the formula is Similarity = cos(u,v).

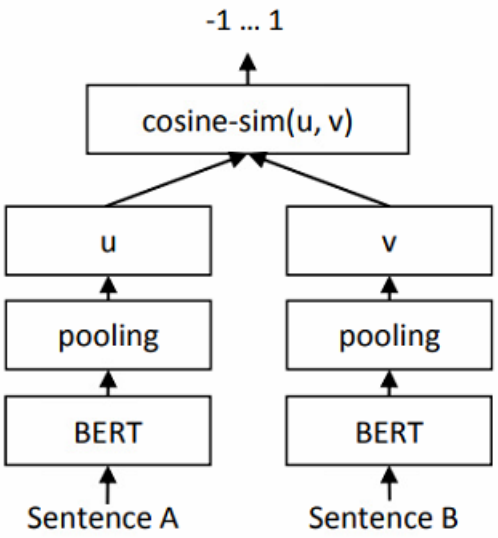

Figure 4. Sentence-BERT Regression Objective Function architecture flowchart

(3). Triplet Objective Function: Given anchor sentence A, positive sentence P and negative sentence N, in order to make the similarity between anchor sentence and positive sentence greater than that between anchor sentence and negative sentence, the distance between A and P is smaller than that between A and N through triple loss adjustment network, as shown in the formula: $\max(||s_a - s_p|| - ||s_a - s_n|| + \varepsilon, 0)$, s_x represents the sentence vector of a, p, and n, and $||\cdot||$ represents the distance and edge parameter ε, ensuring that the distance between s_p and s_a is at least closer than the distance between s_n and ε.

▪3.4.2 Cosine Similarity

In the above-mentioned "Regression Objective Function", cosine similarity is used for correlation similarity comparison. The semantic similarity between sentences is calculated based on cosine similarity, which is expressed by the following formula. Define Pt as the patent text keyword, Ep as the engineering parameter keyword, Tw as the transition word, and EPD as the positive and negative engineering parameter keyword, as shown below:

$$sim(Pt_i, Ep_j) = \cos\theta = \frac{Pt_i \cdot Ep_j}{||Pt_i|| \cdot ||Ep_j||}$$

$$sim(Tw_i, EPD_j) = \cos\theta = \frac{Tw_i \cdot EPD_j}{||Tw_i|| \cdot ||EPD_j||}$$

Through the calculation of the above two formulas, if the cosine similarity value of the patent text keyword and the engineering parameter keyword is higher, it represents the higher similarity between them, and can be used as the recommendation of which engineering parameters the patent is most suitable for. If the value between the transition words and the positive and negative keywords of

engineering parameters is higher, it means that the two have a higher correlation in the description of the patent problem, which helps to find the improving engineering parameters and worsening engineering parameters before and after the transition words.

4. Conclusion

This study proposed a set of preliminary concepts about TRIZ's contradiction analysis, which first constructed the definition mechanism of contradiction problems, then imported patent database and SAO structural semantic analysis. A keyword thesaurus of inflection connective words is collected to perceive the possible contrast sentences in the context of patent, such that the contradiction may be identified. Combined with Sentence-BERT for sentence vector and cosine similarity comparison method, Intelligence Augmentation of corresponding recommendations to assist users in identifying contradiction problems of improving engineering parameters and worsening engineering parameters may be constructed.

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Integration of QFD, AHP and TRIZ for Multipurpose Bookshelf Innovative Design

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Abstract

The bookshelf is a common product in daily life. Currently, most cities face problems as their populations continue to rise while human needs stay constant or expand where citizens are being pushed into less space as cities expand and marketing prices rise. These issues result in the appearance of small houses, flats and small building companies which fail to provide spaces with quality and comfort. This project's primary purpose is to design and develop a multipurpose bookshelf that satisfies customers' requirements and solves problems such as limited space and limited function furniture. To design a multipurpose bookshelf that meets customer requirements. Here applying Quality Function Deployment (QFD) to collect the requirement from customers and translate the respondents' requirements into technical characteristics. Second, the Analytic Hierarchy Process (AHP) collects the designers' and engineers' opinions and input to HoQ as a weight. Through House of Quality to get the main problems. And the TRIZ 39 Parameters and 40 Inventive Principle is then used to identify a suitable solution for the design concept generation. In conclusion, concept 3 Lauve is selected through complete HOQ since this concept obtained the highest relative importance. And the survey of design validation, there are more than 70% of respondents think that this multipurpose bookshelf set helps to save space. Overall, these three methods are used to innovate the multipurpose bookshelf design that satisfies the user's demand while minimizing the space used.

Keywords: Multipurpose bookshelf, Quality Function Deployment (QFD), Theory of Inventive Problem-solving (TRIZ), Analytic Hierarchy Process(AHP)

1. Introduction

Most societies are struggling with population growth and urbanization as a result of increased demand for housing in cities, which has led to the emergence of small apartments. Most small

apartments only have multipurpose rooms intended for several activities like studying, watching TV, having dinner or family gathering (Husein, 2020). Living in tight quarters shouldn't hold you back from meeting your storage needs. With the right strategies, it's easy to live small and store well (Jessica Bennett, 2020).

Based on the description above, people are having a lot of issues with their living spaces and quarters. The first issue is a lack of space in the living room. There is frequently a lack of space in these areas, but a human being requires space when several objects and furnishings surround them. They can get stressed and overwhelmed. To organize space in these places, there must be enough must-have furniture.

According to the observation, there are some problems with furniture usage. The first, have a limited space in the living area. Many small apartments fail to provide spaces with quality and comfort. User's demand is increase since space is not enough (Astonkar &Kherde, 2015; Husein, 2020; Jessica Bennett, 2020) .The second, most of the bookshelf have a boring shelves because they have a lot of the same design and limited function so the multifunction furniture requirement has increase(Furniture et al., 2018; Ikea, 2020). The third, most of the multipurpose bookshelf in the market have a high price range (Xie, 2016).

Phil McKinney said, "Innovation by design is the utilization of a designer's methods and sensibility to address the needs of the consumer. Basically, the goal is to solve more complex problems with the methodology of a designer". So while design innovation will always focus on what a product or service looks like, the real benefit comes from what it does and how it functions in the real world. Design determines how the end-user will experience, interact with, and generally respond to what it is that's on offer. Innovation design is about making things that are both beautiful and useful (Murphy, 2019). There is various research in the journal that uses innovation design to create a product.

There are numerous case studies in the field of innovation design that use various methods. However, the QFD, TRIZ, and AHP were often used, showing that these three methods are important and useful in the field of innovation. Like,Mansor et al., (2014) use the TRIZ, Morphological Chart and Analytic Hierarchy Process method in creating a conceptual design of kenaf fiber polymer composite for automotive parking brake lever. Wu et al., (2020) use the Kano and QFD in developing the baby stroller. Ocampo et al., (2020) are using QFD, AHP, MADM, and AHP in function deployment and decision making. Other than that, Haiyun et al., (2021)use the QFD-based hybrid interval valued intuitionistic fuzzy decision technique to analyse innovation ideas for green supply chain management in the energy business. Next, Carra et al., (2019) use AHP technique in reducing employees' hand-arm vibration exposure through optimal machine design. Khorramshahgol &Al-Husain, (2020) use AGP-AHP approach to Design Responsive Supply Chains for Pareto Customers. These researches shows these methods can be effectively applied in the innovation field.

In summary, this present study is to make the multipurpose bookshelf that is commonly in the market normally has the limited function become more functionality side. The objective of this study is to choose a suitable design that can fit the small space by using the combination of the QFD, AHP, and TRIZ methods. This will help provide spaces with quality and comfort for small homes. The second is to design a bookshelf that is more interesting where it serves multiple activities and purposes at the same time. By altering to multifunctional furniture solutions, it gives full advantage of these reduced spaces while still achieving greater comfort, usability, and order in interesting furniture.

2. Literature Review

In this study, an integrated QFD–AHP–TRIZ design method for creative and sustainable product creation which is multipurpose bookshelf was presented. QFD was used to include the voice of the customer (VOC) and transform the ideas into design options. AHP is then used to collect expert opinions. These design options were associated in a contradiction matrix using TRIZ, and design modifications were implemented into the component. Finally, the best design was chosen using AHP and HOQ.

2.1 Quality Function Deployment

The success of a product or service is mainly determined by how well it meets the needs and expectations of its customers. So, the quality function deployment (QFD) tool collects client feedback and integrates the expected features into the final product (Chaudha, 2011). Dr. Yoji Akao first proposed QFD as a customer-driven product development process in Japan in 1966. It's a collection of tools for capturing user needs, engineering features that satisfy customer needs, and any trade-offs that may be required between engineering features. Without people, nothing occurs. Its starting point is the 'voice of the consumer' (VOC). It also brings together multidisciplinary teams to collaborate on customer satisfaction. QFD also aids in the development of customer-supplier relationships (Fonseca et al., 2020).

The QFD process involves four phases which is the first phase of QFD is a matrix called House of Quality (HoQ), in which the customer requirements are identified and translated into technical requirements. HoQ is vital and important in the QFD system, it is frequently used as a framework to incorporate other techniques, such as ADT and TRIZ. The second phase is product design which is parts deployment. The third phase is process planning and the last phase is process control (quality control charts). Many industries have successfully used QFD to enhance product design, decision-making processes, and customer satisfaction, as well as to prioritise performance measurements (Bouchereau &Rowlands, 2000).

2.3 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a method that can be used as a decision-maker. It is a structured technique that can be used to analyze and organize complicated decisions. In addition, it is presented in the hierarchy structure to show the selection clearly. Professor Thomas L. Saaty first developed the Analytical Hierarchy Process (AHP) in the 1970s, and it has since been widely used in a number of fields (Kousalya et al., 2012).

It's especially useful when there are several possibilities to choose from while making a decision. Complex issues are organized into hierarchical structures using this strategy. The aim, the criteria, and the alternatives are the three levels of hierarchy. The analytic Hierarchy process (AHP) is based on expert judgements to derive the required findings. This technique measures intangibles and then compares how much one element/unit leads another using judgement and software analysis (Rafi, 2013).

Moreover, the Analytic Hierarchy Process (AHP) has been a tool in the hands of decision makers and researchers, and it is one of the most extensively used multiple criterion decision-making techniques. Many notable studies based on AHP have been published, including applications of AHP in many disciplines such as planning, picking the best option, resource allocations, dispute resolution, optimization, and so on, as well as numerical extensions of AHP (Vaidya &Kumar, 2006). This makes the AHP method becomes the most considerable method to use for decision-making (Labib, 2014; Olabanji &Mpofu, 2021; Sirisawat &Kiatcharoenpol, 2018; Vinodh et al., 2014).

2.3 Theory of Inventive Problem-Solving (TRIZ)

TRIZ is the Russian acronym for "Theory of Inventive Problem Solving," a worldwide methodology of creativity established by engineer and scientist Genrich S. Altshuller and his colleagues in the U.S.S.R between 1946 and 1985. According to TRIZ, universal principles of creativity are the basis of innovation. These concepts are identified and codified by TRIZ, and they are used to make the creative process more predictable. These concepts are identified and codified by TRIZ, and they are used to make the creative process more predictable. To put it another way, whatever problem you're dealing with has previously been addressed by someone or somewhere. Finding that answer and applying it to the challenge is what creative problem solving involves. Product development, design engineering, and process management are all areas where TRIZ works great (Jonathan Hancock, 2016).

One of TRIZ's aims is to improve ideality so that the examined system is as near to "an ideal machine" as possible. The major idea is to make sure that every aspect of the analysed system performs a function as a consequence of the requirements analysis. It is a source of ineffective system operation if a system element does not contribute to the implementation of the required function (Pokhrel et al., 2015). The aim of TRIZ is to give designers a strategic problem-solving process that allows them to go closer to the specific innovative solution with the minimum amount of trial-and-error iterations

possible. The four steps of the TRIZ problem-solving process are statement of the problem, problem classification and tool selection, solution generation and evaluation.

3. Methodology

This present study mainly involved three methods which are QFD, AHP and TRIZ. The first stage is data collection and determining the user's needs. in this stage will use specification analysis and position maps to locate the target market and major users. Through the questionnaire survey to investigate the user's needs. Used the expert survey to collect the designer's opinions. The second stage is the combination of all collected and analyzed to build the HOQ. Then, import the TRIZ to get the solutions of the problem solving and the design direction. The third stage is bringing the solution to the design and development stage, using the morphological chart to generate the design concepts. The design concepts will be put into HoQ to evaluate for the final design selection. The last stage is design validation. After the final design is selected, will make a prototype, and conduct the validation. The validation will be according to the respondents' satisfaction as an evaluation.

4. Result and Discussion

4.1 Determine the target market and the user needs

The targeted product data derived from the relevant research paper, market data, network data, and product catalogues were then selected and extracted. And the specification analysis and position maps of the target market were done. Based on the results of position maps, the target market will be selected the single and small families. The major features are such as high space-saving ability and moderately multifunction, modern style and more customized assembly.

Once the target market was selected. Here will use the questionnaire to investigate the user needs. The questionnaire is divided into three parts, one is the basic information of the respondents while the other is the questions about the opinions and needs of the respondents. These questions are categorized based on their attributes and purpose. A total amount has 246 respondents participated in this survey. There are 74.8% which is 184/246 of the respondents are 20-29 years old as the target user.

To summarize, the survey result conclusion can be concluded as below: Most of the respondents faced the problem of limited space in their living areas. They are 20-29 years old. They believe that improving the multipurpose bookshelf can help to solve the problem of limited space. They preferred a minimalist appearance. Most of the respondents chose function and safety as their priorities. Most of the respondents preferred the multi or extra function to fulfil their requirements.

The next stage will be implementing the AHP. Here will implement a questionnaire survey for experts to get the data for the AHP calculations. The questions in the AHP questionnaire are related to the questionnaire survey (User Needs) on the relationship between the criteria and the related technical

characteristics. Based on the questionnaire analysis, the criteria are translated into 12 technical characteristics. The relationship between the criteria and the technical characteristics will be evaluated and reported in table form using the AHP pairwise comparison matrix. Weight is represented by the criterion's average value. These calculated values will be used to determine the relative importance of each technical characteristic in the House of Quality before we can import it into the TRIZ. This questionnaire involves 9 experts and professionals, including product design lecturers, industrial design lecturers, and the owner of a furniture firm.

The results calculated the absolute and relative importance of each technical characteristic by adding the importance of all customer requirements to the correlation value. Based on it, Nice Appearance (9.65%) > Space saving (9.52%) > Multifunction (8.76%) > Mechanism/Structure (8.57%) > Material (8.48%) > Long-lasting (8.29%) > Short set-up time (8.27%) > Cost (7.86%) > Safe to Use (7.76%) > Reliability (7.7%) > Size (7.6%) > Weight (7.53%). It means that the customers will consider the appearance of the multipurpose bookshelf more than other aspects since this technical characteristic obtained the highest relative importance among all the technical characteristics. Table 1 shows the absolute importance and relative importance of each technical characteristic.

Table 1. Absolute importance and relative importance

Technical Characteristic	Absolute Importance	Relative Importance (%)
Nice appearance	4.19	9.65
Material	3.68	8.48
Short set-up time	3.59	8.27
Multifunction	3.8	8.76
Weight	3.27	7.53
Size	3.3	7.6
Space-saving	4.13	9.52
Cost	3.41	7.86
Reliability	3.34	7.7
Mechanism/Structure	3.72	8.57
Safe to use	3.37	7.76
Long lasting	3.6	8.29

4.2 Built HOQ and import TRIZ

The House of Quality (HOQ) is defined as a product planning matrix that is designed to demonstrate how consumer criteria are directly related to the strategies and methods that businesses may employ to meet those objectives. The House of Quality integrates all the data from the AHP calculations. We get to know the user's needs through HOQ and know the expert's views as weight importance through the AHP. Furthermore, to evaluate and choose design concepts, technical evaluation is performed. Based on the given technical goals, the design concepts are rated on a scale of 1 to 5. Then, the absolute importance and relative importance are calculated to know the important criteria.

Then, the highest rank in the complete HOQ will be used as the final design. Through the development of House of Quality, the correlation matrix of the technical requirement is shown on the "rooftop" of the HoQ, and the negative correlation is obtained. In the next step, the negative correlation of the technical requirement is then solved by TRIZ method. When the possible solution is analyzed through the TRIZ, the design direction that would be implemented in the design can be identified. The goal is to quickly create design guidance and concepts for this study.After the HOQ is built, we could analyze the negative correlation matrix from the HOQ rooftop. The negative correlation will be referred to the 39 parameters of TRIZ to match each of them. Through the table, the negative correlation is analyzed based on the 39 parameters and the type of contradiction.

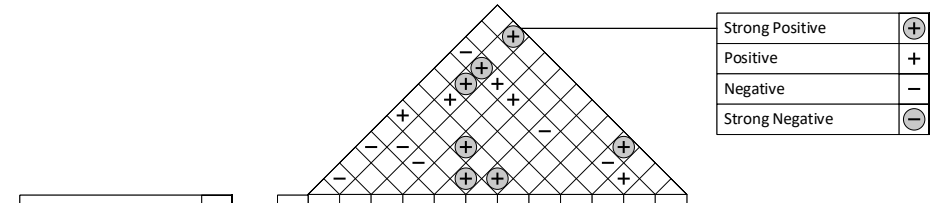
The 40 principles of TRIZ are powerful tools in themselves. Each one represents a strategy for solving a problem. From the 39 parameters problem that we have observed, we could find a solution for the problem in the 40 Principles of TRIZ shown in Table 2.

Table 2. The 40 Inventive Principle for Triz problem

No. of Negative Correlation	39 General Engineering Parameters	40 Inventive Principle
1	12. Shape 14. Strength	10.Preliminary action / 30.Flexible shells and thin films / 35.Parameter changes / 40.Composite materials
2	12. Shape 13.Stability of object	22.Blessing in disguise / 1.Segmentation / 18.Mechanical vibration / 4.Asymmetry
3	14. Strength 2. Weight of stationary object	28.Mechanics substitution / 2.Taking out / 10.Preliminary action / 27.Cheap short-lived object
4	33. Ease of operation 2. Weight of stationary object	6.Universality / 13.The other way round / 1.Segmentation / 25.Self service
5	6. Area of non-moving object 13.Stability of object	39.Inert atmosphere / 8.Anti-weight
6	35. Adaptability or versatility 27. Reliability	13.The other way round / 35.Parameter changes / 15.Dynamics / 24.Intermediary
7	39.Poductivity 12. Shape	14.Spheroidality / 10.Preliminary action / 34.Colour changes / 40.Composite materials

After importing the TRIZ to find the possible solution. The goal is to quickly create design guidance and concepts for the project. Other than that, design direction aims to focus on thinking through the problem and proposing a direction for the project. The design direction for this project where the multipurpose bookshelf design development will focus on this design direction.

To summarize, for the negative correlation 1, we take Principle 10 which is Preliminary action as the solution where it states that we can re-arrange objects such they can come into action from the most convenient place and without losing time for their delivery so the design direction is to design a



Very Important	5
Fairly Important	4
Important	3
Less Important	2
Not Important	1

Customer Requirement/Importance		Technical Characteristic	1. Nice appearance	2. Type of material	3. Short set-up time	4. Multifunction	5. Weight	6. Size	7. Space-saving	8. Cost	9. Reliability	10. Mechanism/Structure	11. Safe to use	12. Long lasting	Requirement evaluation 1. Prosto	2. Semi-Circle Bookshelf	3. Lauve
1. Design	5		0.33												2	4	5
2. Aesthetic	5		0.10												2	4	5
3. Ergonomic	4											0.04	0.18		3	4	3
4. Material	3			0.15			0.46			0.10	0.15			0.15	3	3	3
5. Style	4		0.33												2	4	5
6. Feature	3					0.40					0.13	0.11			3	4	5
7. Creative	3		0.24												2	3	4
8. Flexible	3			0.04	0.13	0.09						0.07			3	4	5
9. Foldable	3				0.19			0.33	0.33			0.13			4	2	4
10. Lightweight	3						0.27	0.33							4	3	3
11. Easy to maintain	3			0.10	0.09					0.12	0.10	0.08		0.14	3	4	4
12. Easy to use	4				0.07	0.22						0.09			4	5	4
13. Reasonable price	3			0.03						0.13	0.15				4	3	3
14. Quality	4			0.16						0.38	0.19			0.35	3	4	4
15. Provide storage	5					0.14			0.28			0.05			4	3	4
16. Easy to store	4						0.09	0.33	0.26			0.11			3	4	5
17. Stable	4			0.05	0.22		0.10				0.11	0.11	0.13	0.10	4	5	4
18. Environment Friendly	4			0.04						0.09			0.12	0.12	4	4	5
19. Safety	4			0.08							0.07	0.05	0.12		3	4	4
20. Easy to assemble	4			0.06	0.30		0.08					0.10			4	5	5
21.Comfortable	5			0.13											2	4	4
22. Can hold object	5					0.15			0.14			0.06			3	3	4
23. Durable	3			0.17						0.16	0.09		0.39	0.15	4	4	5
Absolute Importance			4.19	3.68	3.59	3.8	3.27	3.3	4.13	3.41	3.34	3.72	3.37	3.6			
Relative Importance (%)			9.65	8.48	8.27	8.76	7.53	7.6	9.52	7.86	7.7	8.57	7.76	8.29			
Rating			1	5	6	3	12	11	2	8	10	4	9	7			

Technical Goal		Modern / Minimalist / Casual	Not easily crack / broken	No tool require / set-up within 5 min	Provide storage	Easy to assembly / ≤10kg	Occupy little space / <0.1m3	Create space for something	Fair to product quality / < RM 500	Perform the function anytime	Combine with table/shelf/bed	Stable when using	Not easily broken / last ≥ 5 years	Absolute Importance	Relative Importance (%)	Rating
Technical Evaluation	1. Prosto	3	3	5	3	5	3	3	4	4	3	4	3	355	29	3
	2. Semi-Circle Bookshelf	4	5	5	4	4	5	3	4	5	4	5	4	430	35	2
	3. Lauve	5	4	4	5	3	4	5	4	4	5	5	4	437	36	1

Figure 1. Completed House of Quality

sturdy foldable table that that can ease the customer whenever they need a table as other action. Next for negative correlation 2, we take principle 1 which is Segmentation state that we can make an object

easy to assemble and disassemble so the second design direction is to create a multipurpose bookshelf that is easy to assemble and disassemble to reach a short set-up time.

4.3 Design Development to Final Design

From the morphological chart, the combination of ideas will be chosen according to the technical characteristics and the technical goals with a higher rank. Therefore, 3 sets of the multipurpose bookshelf design are generated.

There are three design concepts for the multipurpose bookshelf that are generated. These three design concepts are the Prosto, Semi-Circle Bookshelf, and Lauve. The final concept for the multipurpose bookshelf was chosen from the House of Quality. According to the HoQ, concept 3 (Lauve) is selected as the final design as it obtained the highest relative importance in House of Quality shown in Figure 1 among the three design concepts. From the HOQ, the technical evaluation is carried out to rank and to select the design concepts. So, through the HOQ rating on the design concept, we got the final design, which is Concept 3 Lauve with a total relative importance of 36 which is the highest one. Lauve comes with a simple and modern style and is characterized by a hexagon shelf for storing objects or books. This makes it possess a high space-saving ability and large storing capability. Besides, it serves multiple functions at the same time such as providing a foldable table, storing objects, and a chair. Figure 2 shows the 3D modelling of this concept built by using Autodesk Inventor software. After the final design is selected, the CAD drawing was created before we can conduct the prototype. The CAD drawing is created using the Autodesk Inventor software. This multipurpose bookshelf set is rendered based on the actual color, material, texture, and appearance. The prototype as shown on Figure3.

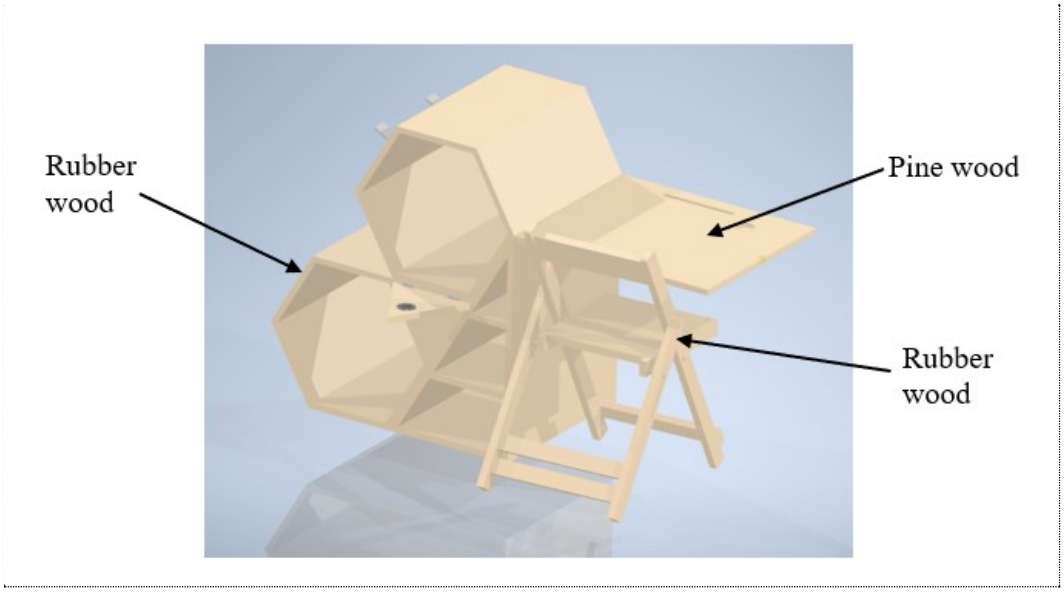


Figure 2. Material of the prototype

Figure 3. Concept 3 (Lauve) was selected as the final design

4.4 Design Validation

After the final design selection and prototype making.The last section is design validation. Here will design a task form to request the respondents to participate to follow and complete the task. After the task, respondents need to give feedback on their satisfaction according to the task and their experiences to the final design (Lauve bookshelf set). There is a total of 20 people who have participated in this design validation which has 3 sections which are section A about basic information, section B is about the opinion about the Lauve bookshelf and lastly, section C is about the evaluation of Lauve bookshelf set.

To summarize, the design validation survey result conclusion can be concluded as below: Most of the respondents are female (55%) and they are 20-29 years old (55%). They are strongly preferred the appearance of the Lauve bookshelf set (85% or 17 respondents). Most of them preferred the function of the Lauve bookshelf set (75% or 15 respondents). They also preferred the multipurpose bookshelf that is all made by wood (55% or 11 respondents). All of them agreed that Lauve bookshelf set is easy to use. Most of them also think that this Lauve bookshelf set helps to save space (70% or 14 respondents). All of them (100% or 20 respondents) had never seen this type of bookshelf in the current market.

5. Conclusions

Since people with diverse backgrounds will have various desires and needs for a product, it is exceedingly difficult to design a product to fulfil all people's desires. In the present study, the combination of QFD and AHP methods is used to prioritize the customers' requirements from various criteria for a multipurpose bookshelf. And got the solution suggestion from TRIZ to find out the solution. The following are the findings of the study:

1. More than 70% of respondents think this multiple bookshelf set helps to save space. According to the validation survey result, most of the respondents agreed that this bookshelf set really can save space since it contains several functions that can be used just in one set and the table and chair can be folded when not in use, so it helps in saving space.

2. The combination of QFD, TRIZ, and AHP methods can conduct the design innovation work systemically. To support process innovation, this three-method integration of innovative tools is proposed. Finally, the importation of TRIZ into QFD can both meet the user requirements and design innovation during the design process.

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Topical areas (Select from listed topics on Call For Papers):

·Technical Conflict Extraction Based on Natural Language Processing

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Abstract

Automatic extraction of technical conflict which contains a lot of human knowledge is significantly for engineer practice. There has been a growing interest in developing automatic information extraction systems for capturing technical conflict from the rich patents files. However, the main research efforts are still focused on extracting abstracts from patent texts. These efforts have brought great convenience but there is still a key problem. The extracted abstracts still belong to unstructured text. Once the number of patents is too large, the extracted abstracts are still difficult to read. This paper proposes a Technical Conflict Extraction Model (TCEM) based on natural language processing (NLP) to automatic extract the technical conflict in given text. Our method defines technical conflict extraction task as the text classification task in NLP and conducted experiments accordingly. This will make the output of our model a structured knowledge and greatly reduce the difficulty of finding targets from a huge number of patents. Our method consists of two main steps. First, this paper constructs a conflict extracting dataset using the TextRank technique and artificial labeling. The main purpose of using TextRank is to obtain abstracts of long-form patent text without using supervised data. Second, our method then need to manually clean and label these abstracts. Finally, this paper builds an end-to-end model to automatically extract the technical conflict from those abstracts. After encoding the contexts with language pretrained model and neural networks, feeding the representation of the text to the classification layer to get the final prediction. According to the experimental results, our model could effectively extract the technical conflict in patents.

Keywords: Deep Learning, Natural Language Processing, Patent, Technical Conflict

1. Introduction

The technical conflicts and their corresponding solutions in the patents are important resources for engineering practice. There have been a few research efforts aimed at automatically extracting technical conflicts from patent literature so that engineers can read the original text in detail to solve

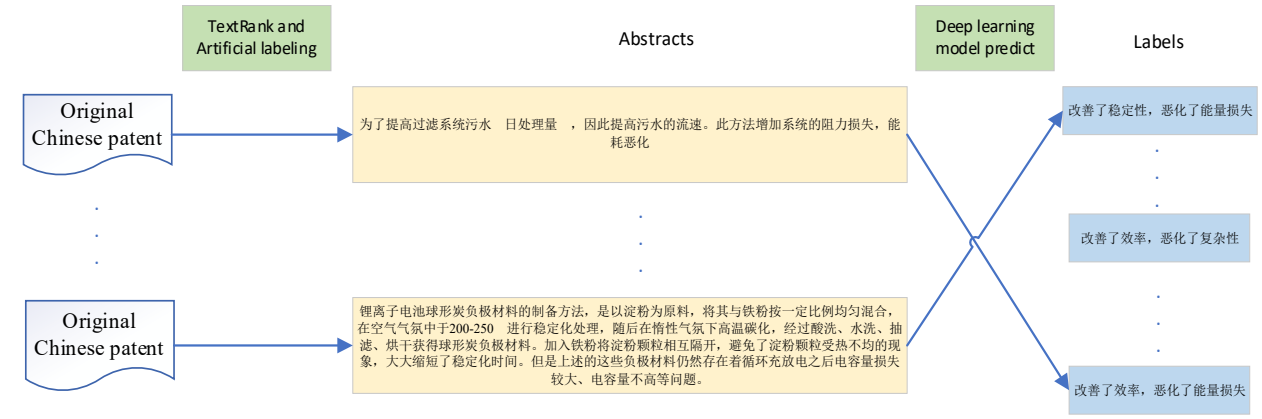

Figure 1: The main step of our method

the problems they meet. Daria and Denis (2021) [1] proposed a method to automatic extract the three main concepts (parameters, partial solutions, and problems) from the patent texts. According to their experimental results, their method has achieved certain results. Guillaume and Ahmed et al. (2021) [2] proposed the transfer learning [3] to technical conflict extraction. With the help of transfer learning, their model can extract abstracts from patent texts while using less labeled data.

Currently, research on automatic extraction of technical conflicts is relatively few. The methods described above all have some disadvantages of their own. For example, the performance of the model that directly extracting the conflict parameters is not excellent. Some models can effectively extract the abstract from the patent text for easy reading by engineers. But the extracted abstracts still belong to unstructured text. Once the number of patents is too large (e.g., 100000), the extracted abstracts are still difficult to read in a short time.

This paper proposes a natural language processing-based method to automatically extract the technical conflict in Chinese patents. The main step of our method is shown in Figure 1. First, our method uses TextRank to get the abstract of the given Chinese patent. The abstract generated by the first example in the figure means ‘In order to increase the "daily treatment capacity" of the effluent of the filtration system, the flow rate of the effluent is increased. This method increases the resistance loss of the system and worsens the energy consumption.’ And after the deep learning model prediction, this patent was finally classified as ‘Improved efficiency, worsened energy loss’.

The contributions of our paper are summarized as follows:

- This research constructs a conflict extraction dataset using the TextRank [4] technique and artificial labeling.

- Our method defines the conflict extraction task as text classification task [5], which make the output of our model a structured knowledge, and help the engineers and researchers quickly filter through many patents to find the ones they need.
- This paper builds an end-to-end model to automatically extract the technical conflict from the abstracts. According to the experimental results, our model could effectively extract the technical conflict in the patents.

2. Methods

▪2.1 Problem definition

Figure 1 shows the main step of our method. The goal of technical conflict extraction is to detect which conflict contains in the candidate sequence. The reason using the abstracts instead of the original texts is that this benefits the encoding of the downstream neural networks.

▪2.2 Dataset construction

This paper builds a new technical conflict extraction dataset from Chinese patents. Firstly, using the TextRank technique to get the abstracts of those patents. TextRank is inspired by PageRank [6]. By partitioning the context into several elements (words, or sentences) and building a graph model. Using a voting mechanism to rank the important components of the text. The reason this method uses TextRank is to obtain abstracts of long-form patents text without using supervised data. Secondly, this method artificially labeled the extracted abstracts to obtain the ground truth of the technical conflicts. In this case, one of the examples from dataset this paper constructed is shown in Table 1.

Table 1. Instance of the dataset this paper constructed

Abstract	Label
解决遥控器容易脏且按键容易损坏问题，为了提高改善系统的“遥控器按键容易损坏”的问题，我们需要改变按键的材料，但这样做了会导致遥控器价格上涨。	改善了强度，恶化了成本

Where the abstract here in Chinese means “To solve the problem that the remote control is easily dirty and the keys are easily damaged, we need to change the material of the keys in order to improve the "remote control keys are easily damaged" problem of the system, but this will lead to an increase in the price of the remote control.” And the label in Chinese means “Improved strength, worsened cost.” In the dataset this paper constructed, a total of 48 technical conflicts are included.

▪2.3 Data Augmentation

For deep learning, labeled data for downstream tasks is highly important. There has been a lot of work aimed at reducing the dependence of deep learning models on labeled data. Such as domain adaptation [7], semi-supervised learning [8] that belong to transfer learning.

But there is actually a more convenient way, data augmentation. This paper introduces Easy Data Augmentation (EDA) [9] to our method. EDA uses four simple but effective data augmentation strategies, namely synonym replacement, random insertion, random swap, and random deletion. The original paper gives the code implementation of data augmentation for the English corpus, here this method uses the Jieba word splitting tool and the Synonyms toolkit to implement the data augmentation for Chinese corpus. Finally, through data augmentation, our method obtains 9 times more labeled data that the source data for text classification. The information of our dataset is shown in Figure 2 and Figure 3.

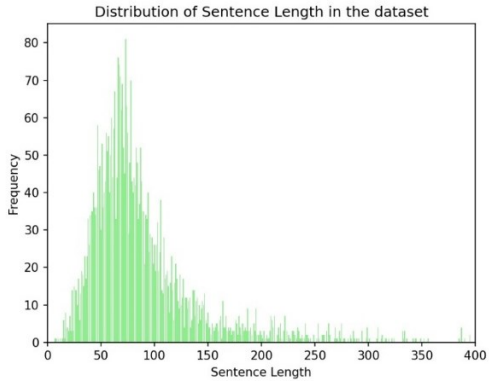

Figure 2 The distribution of sentence length

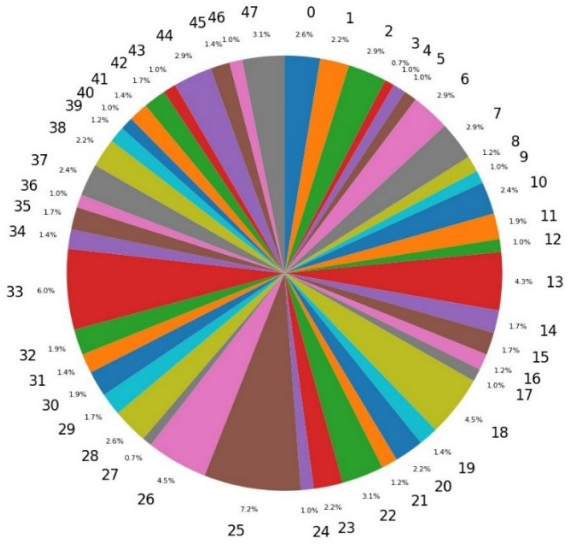

Figure 3 The label's distribution in our dataset

For the label's distribution, the figure only shows the label's index. The specific index and its corresponding label itself, as well as the English translation, totally 48 kinds of label, please refer to Appendix 1.

▪2.4 Overview of our model

This paper proposes a document-level Technical Conflict Extraction Model (TCEM). Through Bi-LSTM(Bi-directional Long Short-Term Memory) [10] and CNN(convolution neural network) [11], our model can efficiently encode the context information. The overview of TCEM is shown in Figure 4.

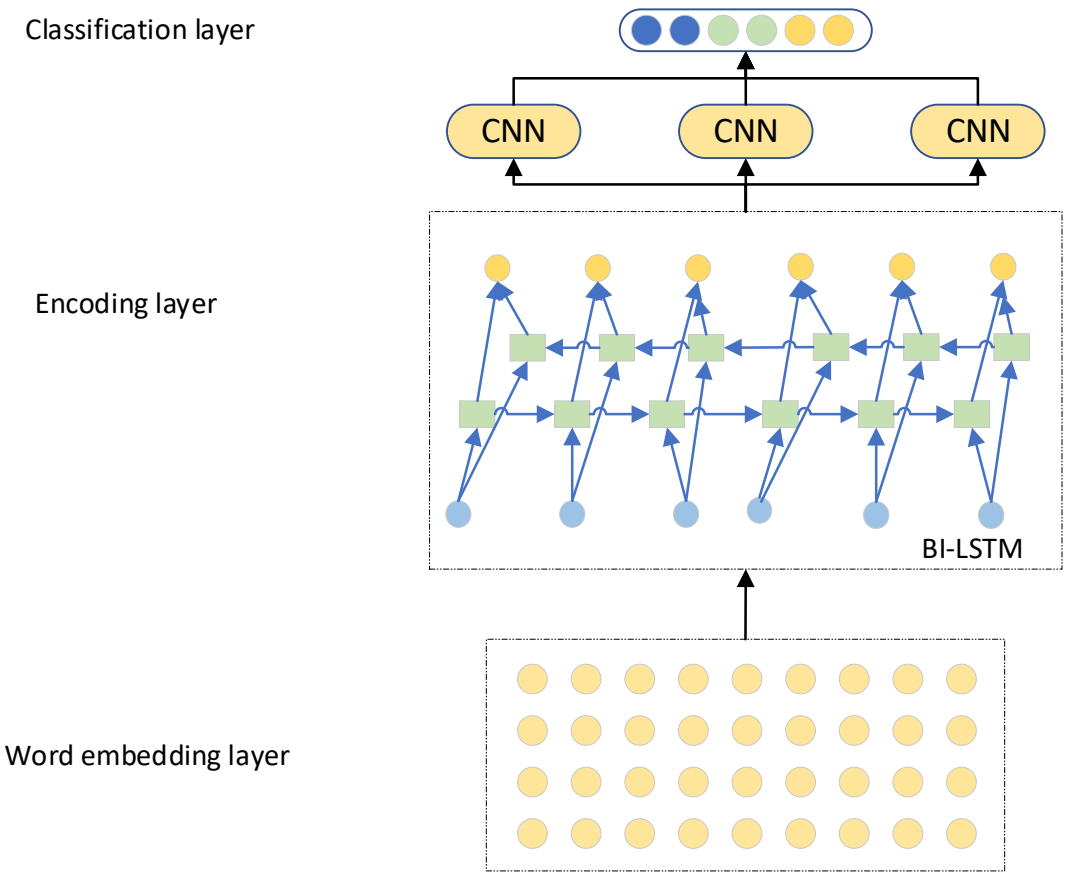

Figure 4 The overview of our model

The TCEM mainly includes 3 layers. The word embedding layer, the encoding layer, and the classification layer.

(1) The word embedding layer

For a given text $T[x_1, x_2 \cdots x_n]$, feeding it to the word2vec [12] language pretrain model to get the context's embedding. The pretrained model [13] TCEM use was trained with SouGou News, released by Li Shen and Zhao Zhe et al. (2018) [14].

$$H[h_1, h_2 \cdots h_n] = Word2vec([x_1, x_2 \cdots x_n]) \tag{1}$$

(2) The encoding layer

Word2vec is a simple but effective model to get the embedding of the text, but it is a static language model, which means that the embedding of one word does not change for different context. To give the text embedding some contextual information, TCEM firstly uses the Bi-LSTM to further encode the text. Recurrent Neural Network (RNN) is a common neural network in natural language processing, has a certain ability to understand the context of long texts. On this basis, Long Short Term Memory (LSTM) has an input gate, an output gate and a forget gate. It could control the amount of input and output information, as well as forget certain data. So the ability to understand long texts has been further improved. But traditional LSTM only considers the unidirectional flow of information. Bi-LSTM also encodes the input sequence from back to front and concatenate them together. Thereby simulating a neural network with bidirectional understanding.

$$H_f = LSTM_f(H) \tag{2}$$

$$H_b = LSTM_b(H) \tag{3}$$

$$h = \{H_f; H_b\} \tag{4}$$

Where H_f and H_b means the encoding from bidirectional information flow. After concatenation in formulation 4, h is the final representation of text after encoding by Bi-LSTM.

Then, our model feeds the representation h to a convolutional neural network (CNN). CNN could learn the local features of text through the convolution computation. The computation formulation of convolution operation at position i of the text could be expressed as follows:

$$c_i = \sigma(W * h_{i:i+s-1} + b) \tag{5}$$

Where σ is a nonlinear activate function, W is a trainable weight matrix and b is a bias parameter. $H_{i:i+s-1}$ means the concatenation of s tokens' embedding in the text.

The convolution operation would be applied step by step. Finally, our method uses the max-pooling to gain the low-dim features. Finally, for each given text, the model get a 768-dimensional vector representation named *logits*.

(3) The classification layer

In the classification layer, our model could classify which label the input text belongs to and compute the loss value of this epoch. TCEM feeds the vector representation of the text *logits* to the linear layer to get the final prediction $logits_{final}$, which is shown in formulation 6. And our model uses the cross-entropy loss to compute the label loss.

$$\log its_{final} = \sigma(W_l \ \log its + b_l) \tag{6}$$

Where σ is a nonlinear activate function (TCEM uses *softmax* here). And W_l is the trainable weight matrix and b_l is the bias parameter.

3. Experiments and discussion:

3.1 Train setting.

Table 2 The Hyper-parameters used in experiments

Hyper-parameter	Value
Word embedding dim	300
Batch size	16
Learning rate	1e-3
Epoch	15
Activate function	Softmax
CNN filter	2,3,4

The experiments are conducted with Pytorch deep learning framework with Nvidia 2080Ti. The optimizer our model used is Adam, and the loss function is cross-entropy function. The other hyper-parameters are shown in Table 2. The original dataset we collated consisted of 418 labeled data. After the data augmentation tool, our method got 9 times more data that the original data. There are 4180 data in total, 3344 for training and 418 each for validation and testing.

3.2 Experimental results

TCEM is a model integrates CNN and Bi-LSTM modules. After the representation of the text is obtained, the text could be further encoded for bidirectional interaction, as well as get more localized context information. The experimental results are shown in Table 3.

The experimental results show that both CNN and Bi-LSTM are very effective encoding neural networks. And TCEM combines the advantages of both, making the ability to extract technical conflicts further enhanced. In the case of using pure CNN or Bi-LSTM encoding, they could only achieve an F-1 score of 94.62 and 92.93 each. But TCEM could achieve 96.04 of F-1 score. The

experimental results also indicate that when using Bi-LSTM encoding, the performance of the model is 1.69 lower than when using pure CNN. This might because the text our model use is the abstract of a patent. And the abstract is already a refined text, and a neural network like CNN for extracting local

Table 3 Compared with pure CNN or Bi-LSTM

Method	Precision	Recall	F-1
TCEM	96.68	96.17	96.04
CNN	95.63	94.74	94.62
Bi-LSTM	93.94	92.82	92.93

feature could better encode such kind of text.

(2) Ablation experiments on data augmentation

It is also worth noting that that our method uses data augmented data in the experiments. The labeled data for downstream tasks is crucial for deep learning models, so this research further tested the performance of TCEM with different numbers of augmented data. The experimental results are shown in Table 4.

Table 4 The performance of TCEM with different number of augmented data

Number of augmented data	Precision	Recall	F-1
0	55.57	43.78	42.51
1x	78.40	70.33	70.85
2x	80.03	73.21	73.33
4x	91.44	89.47	89.41
9x	96.68	96.17	96.04

The experimental results show that the performance of TCEM gradually improves as the data used for training increases. This is in line with the consensus that deep learning models are highly dependent on labeled data. It also indicates that without any augmented data, TCEM only achieved 42.51 of F-1 score. The performance is hardly satisfactory, which illustrates that for technically conflict extraction, reducing the dependence of model on labeled data or trying to increase the labeled data is still the key to the problem.

4. Conclusion

Automatic extraction of technical conflict which contains a lot of human knowledge is significantly for engineer practice. This paper defines the technical extraction task as text classification task and proposed a natural language processing-based method to extract the technical conflict in Chinese patent. According to the experimental results, our method could effectively extract the

technical conflict. In the future, we would like to reduce the model's dependence on labeled data for the characteristics of the technical conflict extraction task and related domain features.

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▪Appendix 1

Index	Class in Chinese	Translation
0	改善了可操作性，恶化了复杂性	Improves operability, worsens complexity
1	改善了强度，恶化了成本	Improves strength, worsens cost
2	改善了可靠性，恶化了可操作性	Improves reliability, worsens operability
3	改善了强度，恶化了可制造性	Improved strength, deteriorated manufacturability
4	改善了形状，恶化了精度	Improved shape, deteriorated precision
5	改善了适用性，恶化了可操作性	Improved suitability, deteriorated operability
6	改善了材质，恶化了成本	Improved material deteriorated cost
7	改善了适用性，恶化了成本	Improved serviceability, deteriorated cost
8	改善了安全性，恶化了可操作性	Improved safety, deteriorated operability
9	改善了稳定性，恶化了能量损失	Improved stability, deteriorated energy loss
10	改善了适用性，恶化了可靠性	Improved serviceability, deteriorated reliability
11	改善了安全性，恶化了成本	Improved safety, deteriorated cost
12	改善了效率，恶化了安全性	Improved efficiency, deteriorated safety
13	改善了效率，恶化了复杂性	Improved efficiency, worsened complexity
14	改善了可靠性，恶化了可制造性	Improved reliability, worsened manufacturability
15	改善了形状，恶化了可制造性	Improved shape, worsened manufacturability
16	改善了静止物体的面积，恶化了效率	Improved area of stationary objects, worsened efficiency
17	改善了体积，恶化了重量	Improved volume, worsened weight
18	改善了稳定性，恶化了复杂性	Improved stability, worsened complexity
19	改善了速度，恶化了物质损失	Improved speed, worsened material loss
20	改善了适用性，恶化了稳定性	Improved applicability, deteriorated stability
21	改善了效率，恶化了精度	Improved efficiency, deteriorated precision
22	改善了适用性，恶化了效率	Improved fitness, deteriorated efficiency
23	改善了适应性，恶化了复杂性	Improved fitness, deteriorated complexity
24	改善了稳定性，恶化了可制造性	Improved stability, deteriorated manufacturability

25	改善了效率，恶化了成本	Improved efficiency, deteriorated cost
26	改善了可靠性，恶化了复杂性	Improved reliability, deteriorated complexity
27	改善了形状，恶化了效率	Improved shape, deteriorated efficiency
28	改善了复杂性，恶化了成本	Improved complexity, worsened cost
29	改善了材质，恶化了效率	Improved material, deteriorated efficiency
30	改善了强度，恶化了适用性	Improved strength, worsened applicability
31	改善了强度，恶化了能量损失	Improved strength, worsened energy loss
32	改善了效率，恶化了能量损失	Improved efficiency, worsened energy loss
33	改善了适用性，恶化了复杂性	Improved suitability, worsened complexity
34	改善了稳定性，恶化了效率	Improved stability, deteriorated efficiency
35	改善了可靠性，恶化了体积	Improved reliability, deteriorated volume
36	改善了形状，恶化了可操作性	Improved shape, deteriorated operability
37	改善了精度，恶化了效率	Improved accuracy, deteriorated efficiency
38	改善了可操作性，恶化了可靠性	Improved maneuverability, deteriorated reliability
39	改善了静止物体的体积，恶化了复杂性	Improved volume of stationary objects, deteriorated complexity
40	改善了稳定性，恶化了形状	Improved stability, deteriorated shape
41	改善了形状，恶化了稳定性	Improved shape, deteriorated stability
42	改善了形状，恶化了复杂性	Improved shape, deteriorated complexity
43	改善了自动化，恶化了复杂性	Improved automation, worsened complexity
44	改善了稳定性，恶化了成本	Improved stability, worsened cost
45	改善了效率，恶化了适用性	Improved efficiency, worsened applicability
46	改善了强度，恶化了精度	Improved strength, worsened precision
47	改善了可靠性，恶化了成本	Improved reliability, worsened cost

Semiconductor stock prices forecasting model based on ARIMA and LSTM

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Abstract

Stock price in finance belongs to the time series data, through the prediction of time series data to determine the rise and fall of stock prices, to achieve the corresponding investment strategy. This paper uses the LSTM algorithm in deep learning and uses MSE to evaluate the good or bad results. By predicting the analysis before and after the epidemic in Taiwan stocks. Show the increasing volatility of the stock and the better MSE of residual.

Key word: RNN, LSTM, Deep Learning, IC, chip, stock forecast

1. Introduction

The stock market has always been a leading indicator of the country's economic development. The rise and fall of stocks represent the economic climate and the company's strengths and weaknesses. In particular, the company's operating performance is often reflected in the stock price. In addition to the company's operating performance, the company's stock price will be affected by some political and economic policies, especially multinational enterprises.

In recent years, the competition for semiconductors is accelerating. It is reported that on January 20, 2022, President of the European Commission Von Delain announced at the video conference of the 2022 World Economic Forum that the EU Chip Act will be carried out in February, with the aim of increasing the EU chip production capacity from 10% of the world at present to 20% by 2030. By 2030, the EU will invest about 45 billion euros to support chip production, pilot projects and start-ups, and the most important thing is to build large chip manufacturing plants. [4]

And on August 9, 2022, President Biden of the United States officially signed the 2022 Chip and Science Act (referred to as the Chip Act). The bill involves an overall amount of about 280 billion dollars, including about 52.7 billion dollars in financial support for the semiconductor industry, 24 billion dollars in investment tax credits for enterprises, encouraging enterprises to research and develop and manufacture chips in the United States, and about 200 billion dollars in scientific research funding in the coming years. [5]

It can be seen that countries are taking the semiconductor industry as the main development focus, affecting Taiwan TSMC, South Korea Samsung, Japan and other semiconductor related enterprises. TSMC has always been a technology leader in the semiconductor industry, and recently has been a brilliant performance in the stock price, which has aroused our high concern about TSMC's stock price.

In the financial field, time series forecasting is an important method to study the volatility of the securities market. Using the historical data generated in the financial market, a forecasting model is established to tap the inherent volatility rules and predict the future trend. As a special kind of serial data, time series not only has the commonness of time series, but also can obtain the noise that may be contained in the data; It also has the particularity of data, such as the non-linear relationship between data, which makes it more difficult to grasp its fluctuation law. Therefore, how to accurately reveal the change trend of the time series and reasonably predict the time series is the focus of the academic community.

As a time series, LSTM has three advantages in predicting the stock price trend. First, we can find potential characteristics in the stock price, and then make more accurate predictions. Second, in the time series, due to the part of the forgetting matrix, compared with RNN, it can grasp a better contour without divergence. Third, compared with ARIMA, the algorithm is based on a fixed number of calculations, so it can teach ARIMA to be accurate for larger events.

The research objects of time series prediction are diverse, and the research methods have also undergone extensive evolution, from statistical models to intelligent models, from single models to composite models. Statistical models, represented by ARIMA model and GARCH model, are widely used.

LSTM initially needs to solve the problem of the weight of vibration and the problem of too long execution time.

Considering the output of experimental results, the corresponding equipment and software are introduced here. The GPU model used in this experiment is Geforce RTX 3070 ventus 3x. The driver Cuda version is 11.7. The development environment uses Ubuntu 18.04 LTS and Jupyter notebook for programming. Related packages include numpy, pandas, matchlotlib, seaborn, sklearn, torch, time, math, and plotly.

The stock data source is from Wanda database, and the algorithm is from github [1]. The information includes TSMC stocks, which are denominated in Taiwan dollars. MSE method and loss curve are used to evaluate the algorithm. TSMC's share price will be from March 18, 2004 to September 5, 2022.

The process can be roughly divided into three parts: sorting out data, training models, and forecasting stock prices. In terms of data sorting, LSTM has more complex characteristics, and many parameters need to be set. In terms of training model, ensure that the correlation matrix is large enough to conform to the algorithm. Also, the MSE of the training model needs to be evaluated. The final MSE of the loss function is 0.00035. In terms of stock price prediction, the MSE predicted by the training set is 37.30, while the MSE predicted by the test set is 24921.10.

2. Method

2.1. ARIMA

ARIMA model is a combination of autoregressive moving average (ARMA) model and difference model, and ARMA model consists of autoregressive (AR) model and moving average (MA) model. ARIMA (p, d, q) model is mainly used to solve the prediction problem of non-stationary time series. The non-stationary time series are obtained by d-order difference operation, and then predicted by ARMA (p, q) model. The mathematical expression of ARMA model is as follows:

$$X_t = c + C_t + \sum_{i=1}^{p} \alpha_i X_{t-i} - \sum_{i=1}^{q} \beta_i \varepsilon_{i-q} \quad (1)$$

For the prediction of financial time series, the construction steps of ARIMA model are as follows:

Step 1: Stability test. The stationarity of the original data is tested, and the non-stationary time series data is smoothed by the difference method. After the first order difference, check again whether it is stable. If it is not stable, repeat the difference operation.

Step 2: Determine the model parameters. Among the main parameters of ARIMA (p, d, q) model, d is the number of difference times in step 1. The determination of p and q is mainly based on the observation of autocorrelation function and partial autocorrelation function images and the combination of AIC criteria. It is generally believed that the smaller the AIC value, the better the effect of the parameter model.

Step 3: Residual inspection. After determining the model parameters, check whether the residual of the model fitting result conforms to the white noise sequence. If yes, the model is selected well. If not, repeat the above steps to determine the parameters again.

2.2. LSTM

Long Short Term Memory was first proposed by Hochreiter and Schmidhuber in 1997. Solve the problem that RNN weight disappears during reverse transmission. It mainly introduces the method of forgetting gate to solve the problem of weight loss.

Explain the steps in order:

The first step is to inspect the stock price profile and verify the segmentation profile of the subsequent training set and test set. Normalize the data, change the value between [- 1,1], so that the model can be read and trained. The segmentation method uses 0.8 ratio as the training set and 0.2 ratio as the test set. At this time, there were 3634 training sets and 908 test sets. At this time, the data has been processed. The number of training samples at a time is set to 20. At this time, you can view that the size of the training sample matrix is (3634,19,1), and the size of the test sample matrix is (908,1).

The second step is to set relevant parameters before training the model, because the stock price belongs to the time series and only corresponds to a single value. The input and output dimensions are set to 1, the hidden layer is set to 2, the hidden layer dimension is set to 32, and the number of overlapping is set to 100.

Table 1. Initial Parameter

Parameter	Value
input size	1
hidden size	32
numbers of recurrent layers	2
output dimension	1
numbers of epochs	100
batch size	20

Establish the model LSTM. The algorithm steps are described below.

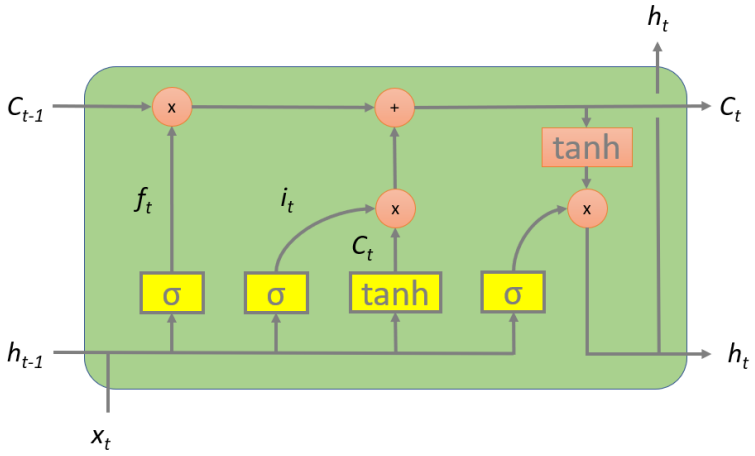

Figure 1. LSTM Network Architecture

Table 2. Symbol definition

Symbols	Definitions
h_t	the hidden state at time t, h_0 is the initial parameter
c_t	the cell state at time t, c_0 is the initial parameter
x_t	the input at time t
i_t	the input gates at time t
f_t	the forget gates at time t
g_t	the cell gates at time t
o_t	the output gates at time t
$x_t^{(l)}$	the input of l-th layer (l>=2)
$h_t^{(l)}$	the hidden state of l-th layer (l>=2)
σ	the sigmoid function
$\odot$	the Hadamard product
W_{xy}	the weight with dimension (x,y)
b_{xy}	the bias with dimension (x,y)

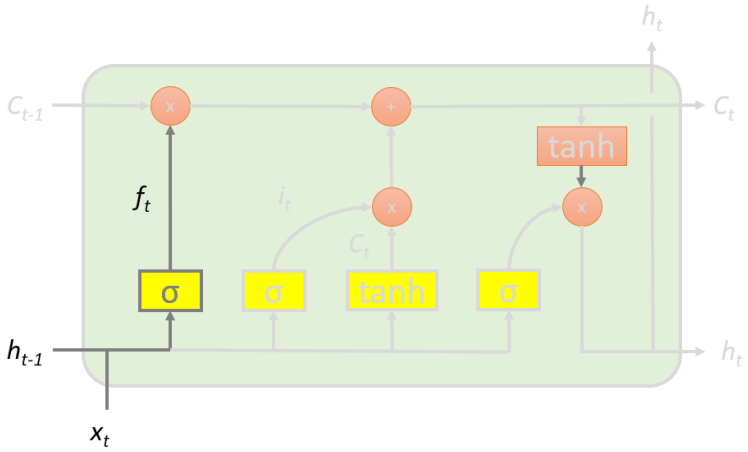

Figure 2. forget gate at time t

$$f_t = \sigma\left(W_{if}x_t + b_{if} + W_{hf}h_{t-1} + b_{hf}\right) \quad (2)$$

Enter the Forgotten Gate first to decide whether to use the previous cell state. Output 1 represents adoption, whereas output 0 represents complete abandonment of the previous state. The initial matrix h will be given_ 0 and c_ 0 to assist in matrix algorithm execution.

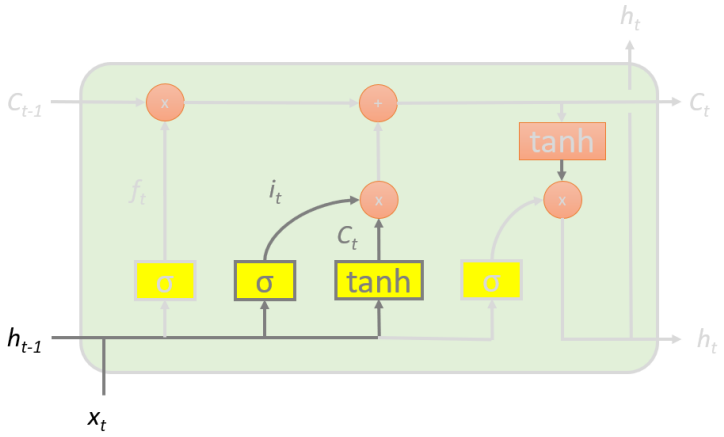

Figure 3. input gate and cell gates at time t

$$i_t = \sigma(W_{ii}x_t + b_{ii} + W_{hi}h_{t-1} + b_{hi}) \quad (3)$$

$$g_t = \tanh(W_{ig}x_t + b_{ig} + W_{hg}h_{t-1} + b_{hg}) \quad (4)$$

Decide which part of the status needs to be saved, including the input gate and the cell gate. The input gate determines which values need to be updated, while the cell gate determines that candidate values can be added and updated.

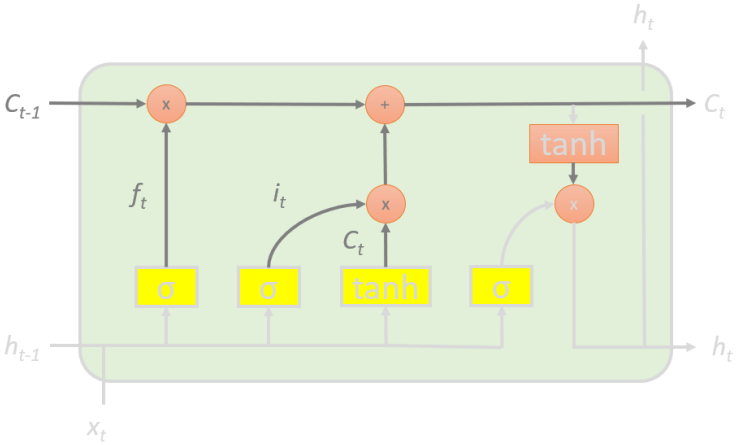

Figure 4. cell state at time t

$$c_t = f_t \odot c_{t-1} + i_t \odot g_t \quad (5)$$

In order to update the cell state, the Forgotten Gate and the cell gate judgment are added.

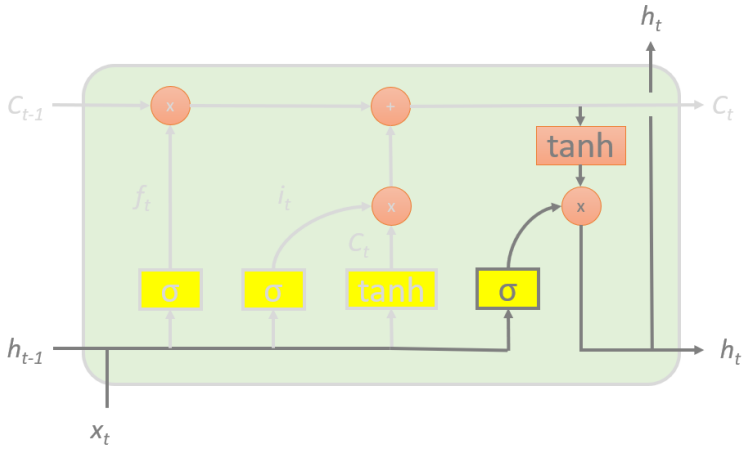

Figure 5. output gate and hidden state at time t

$$o_t = \sigma(W_{io}x_t + b_{io} + W_{ho}h_{t-1} + b_{ho}) \quad (6)$$

$$h_t = o_t \odot \tanh(c_t) \quad (7)$$

Finally, you need to decide whether to pass the output gate. The opening of the output gate depends on the cell state. When it is determined to be open, in order to limit the value to [- 1,1], multiply tanh to get the hidden state.

At this time, the LSTM model is introduced for training, and the loss function is checked for convergence in the middle. Evaluate using MSE.

$$MSE = \frac{1}{N}\sum_{i=1}^{N}\left(y - f(x)\right)^2 \quad (8)$$

Adam is used as the optimizer. Finally, the original data is predicted, the contour is obtained, observed and compared.

The third step is to predict the test set and insert the original data to compare the contour. At the same time, conduct MSE for evaluation.

3. Results and Discussion

Figure 6. TSMC stock price

The Close Price of 2330.TW show the increasing in the period of COVID-19. The data range is between March 18, 2004 and September 5, 2022. The COVID-19 begin at the end of 2019, meanwhile, the price increase unproperly.

Figure 7. Train predict and actual value

With the training model, predicting the trend is similar to actual data, with the MSE is 37.30. It demonstrate that LSTM work with the front 80% data. The front 80% data end up November 14, 2018. It is the year before the COVID-19.

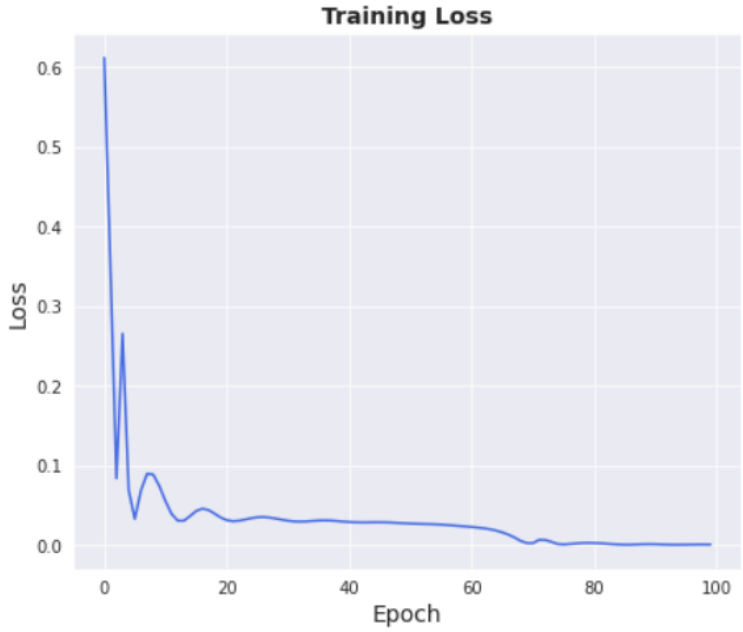

Figure 8. loss function

Concerning the loss of the model, it took 100 epochs to loss of 0.036, and it took time around 22 second.

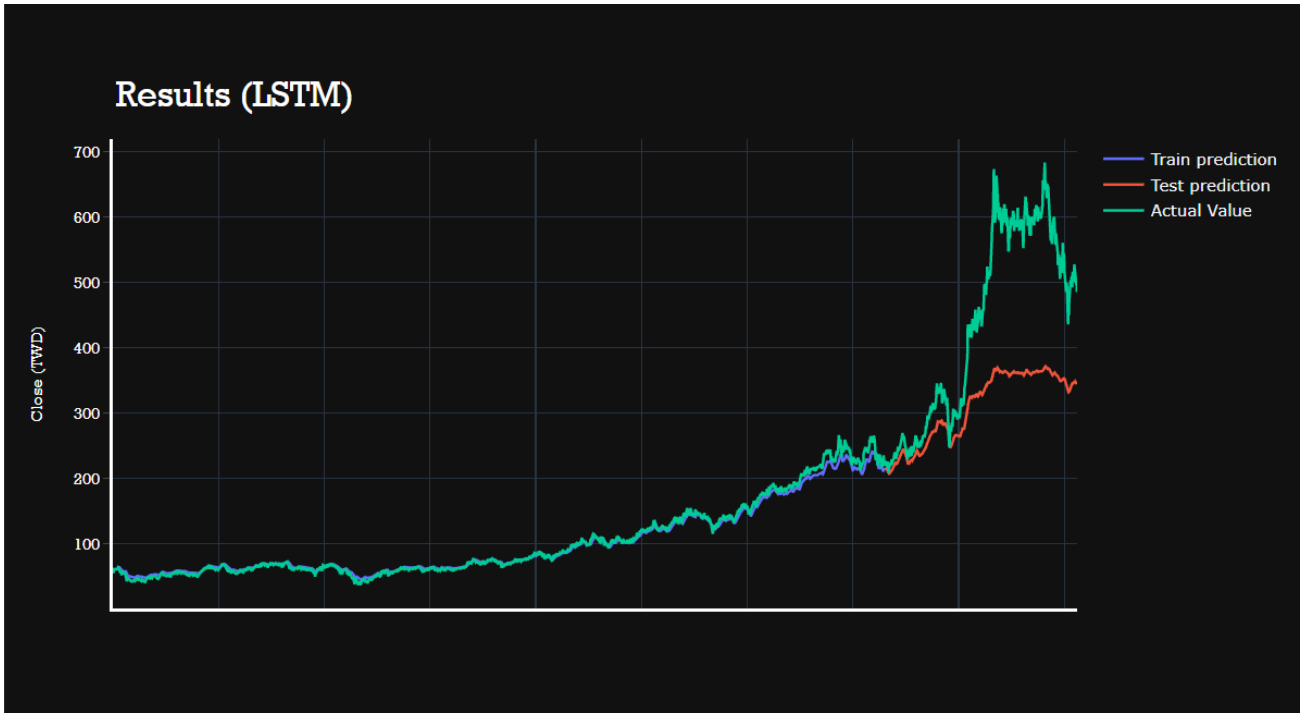

Figure 9. LSTM train predict, test predict and actual value

The figure show that it has bad prediction in the COVID-19 period. Prediction represents the proper situation. The actual value will decrease whether Chip Act pass. The MSE is 24921.10. It representation the market volatility increasing.

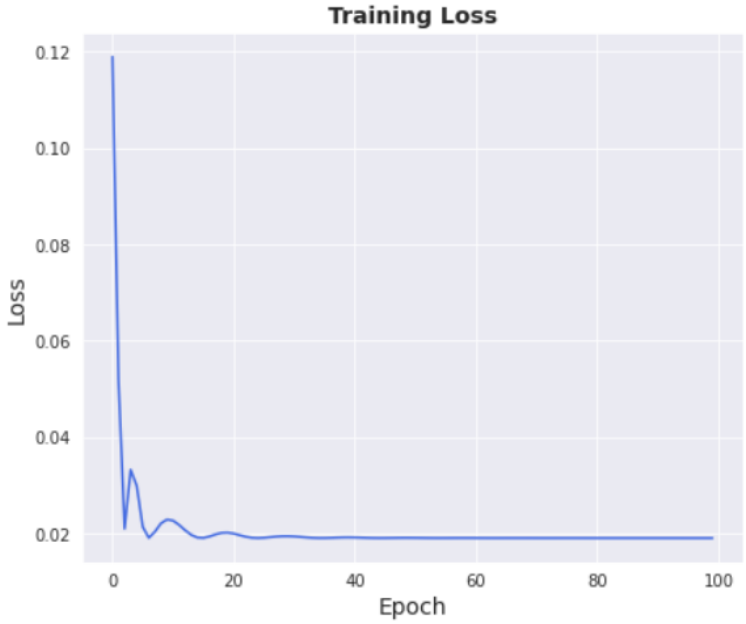

Figure 10. Figure Loss function of residual

It convergence at 0.02.

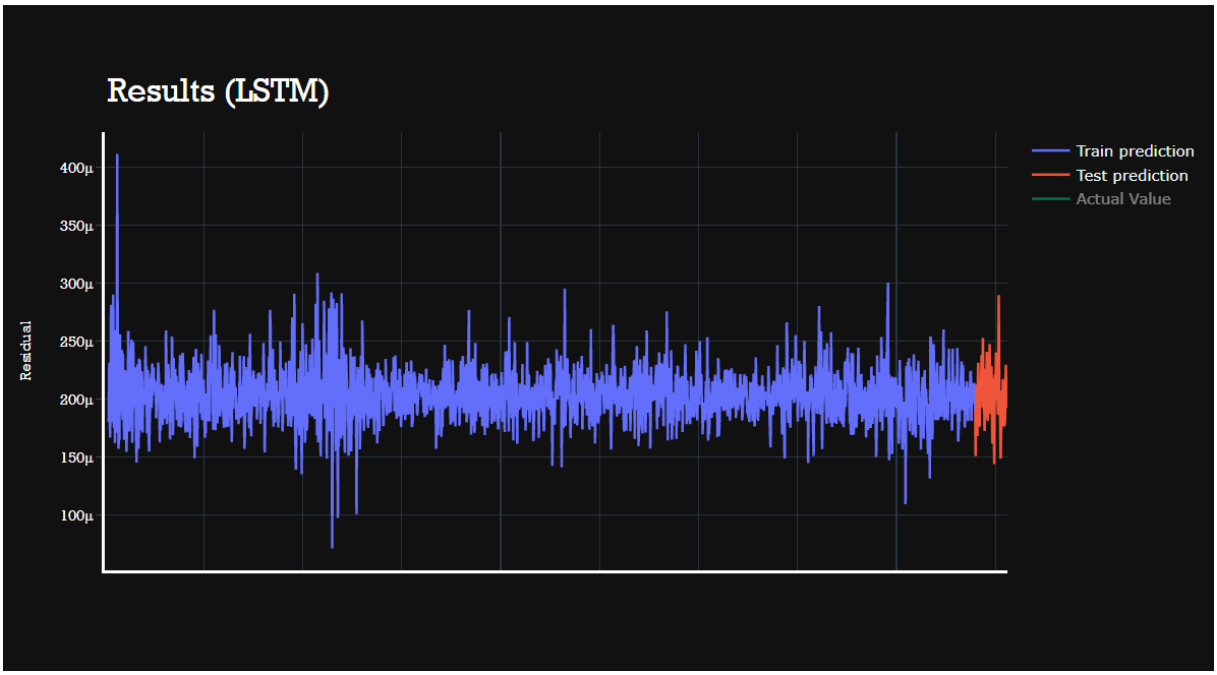

Figure 11. Train prediction and Test prediction

The residual show the predict residual and train residual.

The MSE of ARIMA's residual is 6.10e-5, and the MSE of LSTM's residual is 6.07e-5. The LSTM has the least value of residual.

4. ▪Conclusion

LSTM find the feature behind the Close Stock Price. Although Chip Act pass, it still obey the market rule. In the short term, the TSMC will be decreasing. In the long term, it return at 2018. In the future, it can continue how Chip Act work.

LSTM has the less residual than the ARIMA, so predict precisely.

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基于 TRIZ 的电解装置创新设计

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中国科技部创新方法工作专项（项目编号：2017IM010200）

中国科技部防疫专项（项目编号 2020IM010200）

摘　要

本项目自获悉市场需求信息开始,于 2019 年即开展以消毒水技术及产品的二项专利导航，进行专利检索、分析、评估等，面对同类现有技术的目标专利上所存在的“专利风险”，以及满足 2020 年抗疫的市场急需，应用《系统性专利规避再生与强化》[1]等 TRIZ 理论方法进行对目标专利规避、再生、强化以及扩展与布局。具体的应用：对目标专利上的再生与规避,经裁剪、替代，以及对组件、功能的改/换、加、减、拆，形成全新的“电解装置”；通过专利强化,应用演化趋势和关联系统的扩张，将“电解装置”扩展，即“电解装置”与容器或结构结合，开发出 5 款新产品,形成 35 件中国专利申请方案(2 发明 14 实用新型已授权),初步呈现合理的专利布局。本项目对 TRIZ 的贡献是结合抗疫之急需，应用专利规避、再生、强化的创新方法实现新产品之研发、新专利扩展与布局,助力培育高价值专利。

关键词：电极、专利规避、专利再生、专利强化、喷壶、喷枪、电解装置、消毒杀菌、专利扩展、专利布局

一、新品研发

新冠疫情防控期间，可用的如次氯酸钠消毒水是食盐水或生理盐水的电解产物，是一类很好的含氯消毒杀菌剂，其设备如项目单位某品牌的消毒喷壶就是抗疫防控的一种有力武器。该设备以食盐水或生理盐水（特殊情况下）作为原材料，通过直流电解反应产生以次氯酸钠为主的溶液。达标的次氯酸钠溶液都是强氧化剂和消毒剂，它是通过取自来源广泛、价格低廉的食用盐稀溶液，经无隔膜直流电解而产生的。次氯酸、次氯酸钠的化学性质并不稳定，用后经时间或温度考验，即分解成无毒无害物质，使用时最好一边制备一边使用。但是现有工业技术中的次氯酸钠发生器体型较大不方便搬运，造成使用不便；而一般的小型发生器则反应生成的速度较慢，也会造成使用不便。在使用方式上，有的开发出电动喷雾，有的是手动按压喷水雾等款式，各有优缺点，因此限制了电解产生次氯酸、次氯酸钠设备在环境消毒领域以及其他领域的应用展开。综上所述，现有的此类消毒产品，结构简单，功能单一，用途不广泛，使用不理想，无法做到抗疫与平时生活需求兼顾，难以满足广大消费者的多种使用需求。

因此，如何实现一种专用的消毒器械，且消毒器械体积小，携带移动方便，反应速度快，清洁消毒效果好，功能多样、用途广泛的消毒器械等是业内亟待解决的技术问题。

我公司自 2018 年下半年起，已走到国内同行企业的前头，就开始研发消毒技术与产品，一种小型手持式电动消毒喷壶及其电解装置，如图 1、2；同时段，已申请《一种多功能空气净化用高效电解水喷壶》[2]等相关发明专利 23 件。

图　1

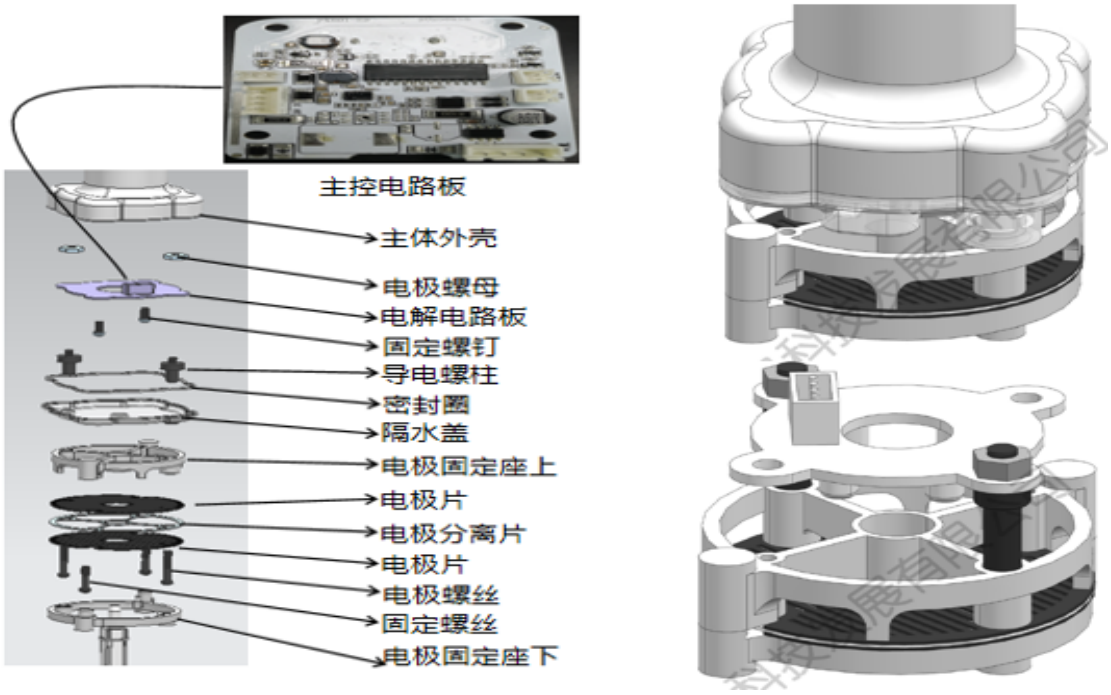


图 2

2020 年以来，突发的新冠肺炎疫情让国人措手不及，戴口罩、勤洗手、常消毒，是日常必需的防护手段。抗疫市场催生了含氯消毒产品迅猛增长，我公司在第一时间捐赠了一批手持式电动消毒喷壶于 2020 年 1 月 22 日下午到达武汉金银潭医院（1 月 23 日武汉封城），几天后又有 200 余台消毒喷壶抵达湖北孝感地区医院。此后逐月均以数百台计增长，应对抗疫市场需求。

满足抗疫需求的同时，也得市場的积极反馈，国内的如武汉金银潭医院第一反应：医院一线应急所需，可否用生理盐水替代食盐水？普通消费者反应：防疫产品普惠价格问题，防疫产品多样化问题。另外，韩国代理商反映，韩国市场同类产品出现，甚至涉及产品专利问题。总之，防疫产品市场需求旺盛，抗疫持续创新十分必要。

二、专利导航

公司作为国家级知识产权示范企业，十分重视企业专利导航，凡有新上重大研发项目均辅以专利导航先行。为此，自 2019 年 2 月起，先后委托上海段和段律师事务所和江苏伯腾科技有限公司开展专利评议报告[3]和专利导航分析报告[4] 。二合作单位从不同技术角度出发，都发现韩国的一家公司（格伦特克有限公司、吴景姬等，）相关专利具有一定的风险，如下表 1 风险专利情况表[5]；该韩国公司也是韩国市场上与我产品的竞争者。

表 1 风险专利情况

序号	申请日	申请人	发明人	申请号	专利类型	专利名称	法律状态
1	20151222	格伦特克有限公司	**吴景姬**	CN201530548971.5	外观设计	喷枪	授权

2	20100303	格伦特克有限公司	赵金一	CN201010128513.2	发明授权	用于生产无菌水的单元、包括所述单元的筒以及包括所述筒的洗衣机	授权
3	20121012	格伦特克有限公司	金万根	CN201210387201.2	发明授权	出入水部在一侧的杀菌水生产卡盒	授权
4		韩国公司		KR101880970	发明授权	PORTABLE STERILIZE WATER SPRAY GUN TO RECYCLE RESIDUAL WATER（便携式杀菌余热回收水的喷水枪）	韩国授权-

三、专利分析

上述公司专利主权项，即“电解单元”，由一对电极、中空的电极分离器、电极棒，以及框架组成。该“电解单元”与我产品中“电解装置”相似度很大，存在侵权风险。同时,按专利导航提供信息找到同类的《一种制备次氯酸的电解装置》[6]，同样有电极片、垫片（电极分离器）、导电棒，以及盒体（框架）组成，该发明专利于 2018 年 4 月授权，被认为是最接近的“现有技术”。二专利的电极模块或电解装置其功模型图如图 3、图 4。比较二者功模型图（认定为目标专利）,可知其不同之处主要表现在“分离器”与“导电棒”上，韩国专利“导电棒”更复杂。为此，认为二目标专利的出现，形势严竣,迫在眉婕,必须立即开发新的电解装置与新形喷壶,已构成我司新一轮创新改进的重大目标。

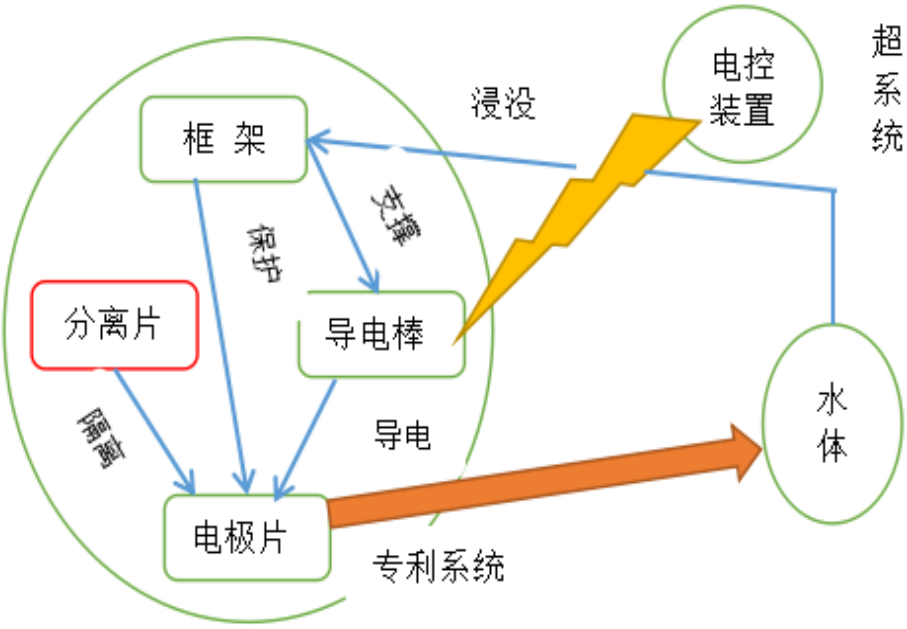


图 3

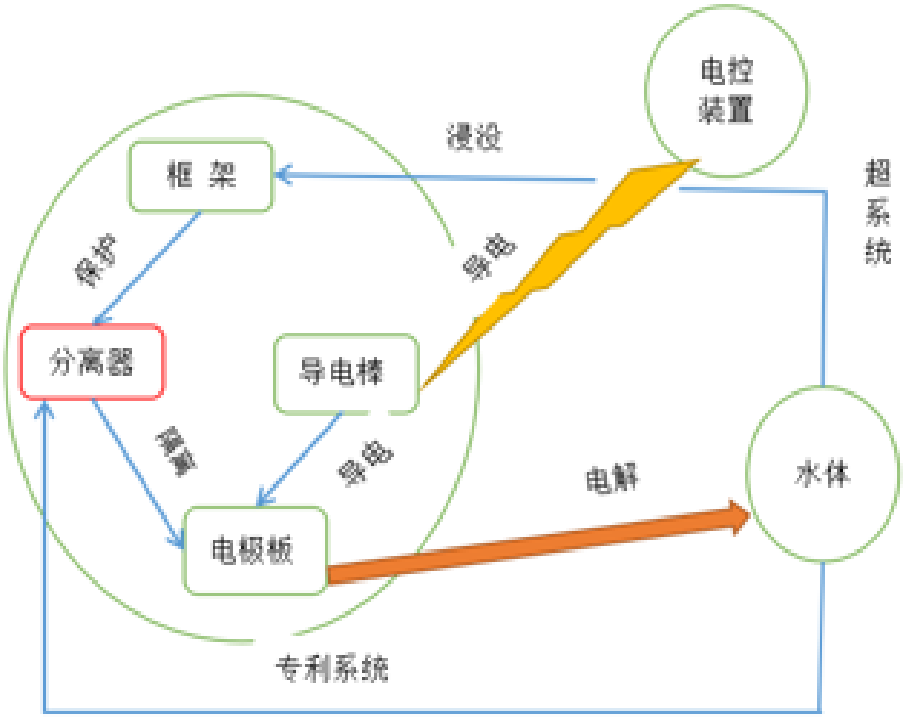


图 4

四、专利规避

所述专利规避[7]是按照《系统性专利规避再生与强化》理论，着重于技术层面进行探讨，而不针对法律层面的规避，即在：

组件规避：改/换、加、减、折；

功能规避：改、加、折；

作用原理规避：改、折。

4.1.组件规避

应用“组件规避刺激思维表格”，对目标专利主权项中电极片、分离器、导电棒、框架 4 大组件及功能模型逐个、逐条箭头进行针对刺激思维问句而发想，见表 2。

表 2 分离器规避刺激思维表

当前功能	当前功能分离极板，可以为独立项特征功能，主要功能，或任一功能，		
通称功能	通称功能：隔离		
资源 DB 可用资源	可分隔、连接、固定的物件或构件	周边资源库	水体、线路、上座体
系统内部资源	电极片、导电棒、框架		

刺激思维问句	1. 系统内部的其他组件是否能提供现有特定或通称功能取代原工具形成概念解答? 2. 资源 DB/周边资源库的组件是否能提供(工具)现有特定或通称功能形成概念解答? 3. 能否加入添加物，改变工具特性产生类似的特定或通称功能? 4. 现有组件是否能拆解为两个或三个以上的组件来执行现有特定或通称功能?	
工具/ 受件	操作元	想法
{填入特征功能工具}	换-改	{由思维问句 1 与 2，改：分离片带连接、固定的构件，凸起或凹块；
	加(添加物)	{由思维问句 3，填入添加物：封胶（ABS 树脂）；
	减	可减
	拆解	边缘凹凸块，中心隔离凹片
{填入特征功能受件}	换-改	由思维问句 1 与 2，思考可以换/改的组件，网格状电极片；
	加(添加物)	由思维问句 3，思考可以填入添加物的解答概念，网格状电极片涂复导电橡胶，平整表面，同样导电；
	减	可减
	拆解	电极板部分为电极片，部分为平面或折弯的连接片,网格状连接片涂复导电胶，加强电性连接；

4.2 功能规避

利用“功能规避刺激思维表格”，对目标专利主权项电极片、分离器、导电棒、框架 4 大组件以及功能模型图逐个、逐条箭头进行针对刺激思维问句的发想。见表 3。

表 3　　功能规避刺激思维表

功能: {分离器+隔离+电极片}	通称功能: 隔离	价值:巩固隔离
刺激思维问句	1. 能否用其他功能来替代现有功能? (运作原理可以一样或改变) 2. 能否加入其他功能来达成现有价值? (可由 effect DB 去找) 3. 能否把现有功能拆解成两个或三个以上功能? (可由 effect DB 去找) 4. 能否用其他运作原理来完成现有功能? (通称功能可由 effect DB 去找) 5. 能否把现有功能的运作原理拆解成两个或三个以上的运作原理? (可由 effect DB 去找)	
	想　　法	
改变功能	改变框架的固定、支撑功能为隔离水体的主要功能。	
加入其他功能	电极板持有电解功能外，增加导电功能； 分离器的隔离功能外、另产生连接、固定、支撑功能。	
拆解功能	电解功能拆为电极片--电解部，连接片--导电部（替代导电棒功能）。	
改变运作原理	原由框架、导电棒起到连接、固定、支撑作用的改为分离器上的凸起和凹槽以及基板的局部来承担。	
拆解运作原理	原由框架、导电棒起到连接、固定、支撑作用的拆解为基板、电极片的部分	

经过上述专利再生与规避，电解装置产生许多全新构思，其中，如图 5：电极片的改进:第 4 平面型、第 5 折弯 L 型；既有电解功能部，又有导电功能部。如图 6：分离片的改进:有 A、B、C 三种款式，除保持分离功能外，增加了固定、支撑功能。其中，图 7 中为目标专利功能模型图；中图裁剪了导电棒，其功能由电极片的连接部替代；下图中导电棒与分离片均被裁剪，由超系统中电控板上导线直接穿过基板与电极片的连接部焊接。中、下图中二专利新点子均已申请专利。

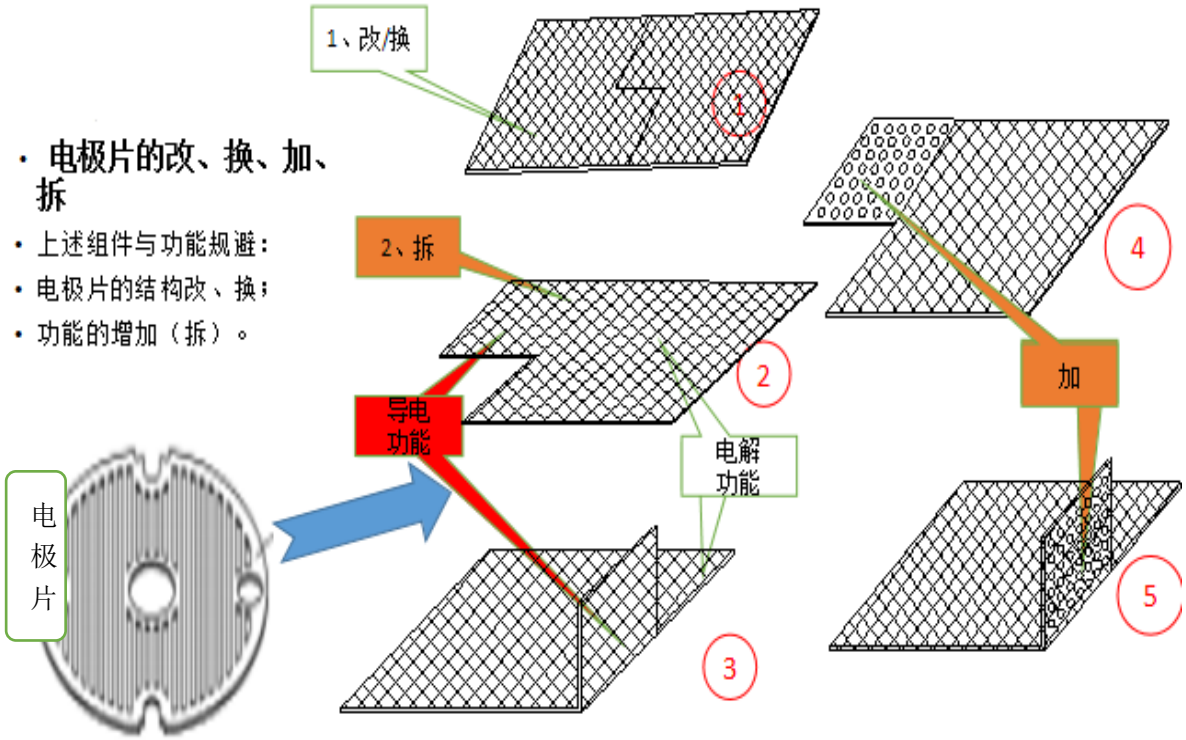
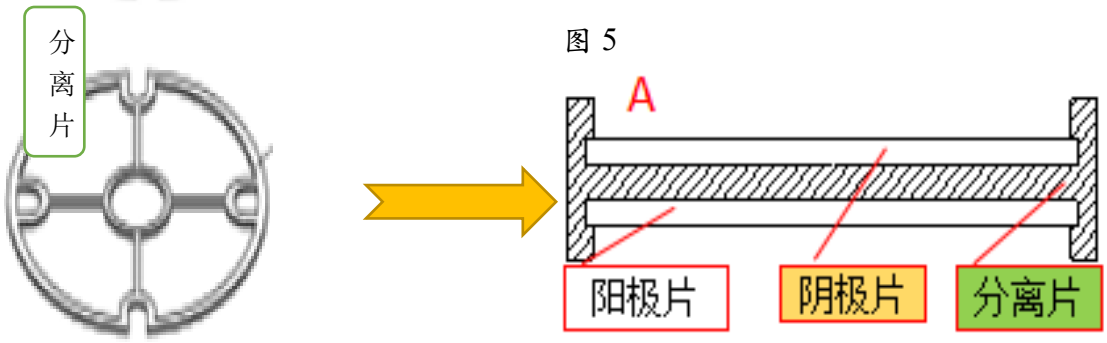


图 5



分离片改、换、拆以及功能的增加，产生分隔、连接、支撑与固定功能。

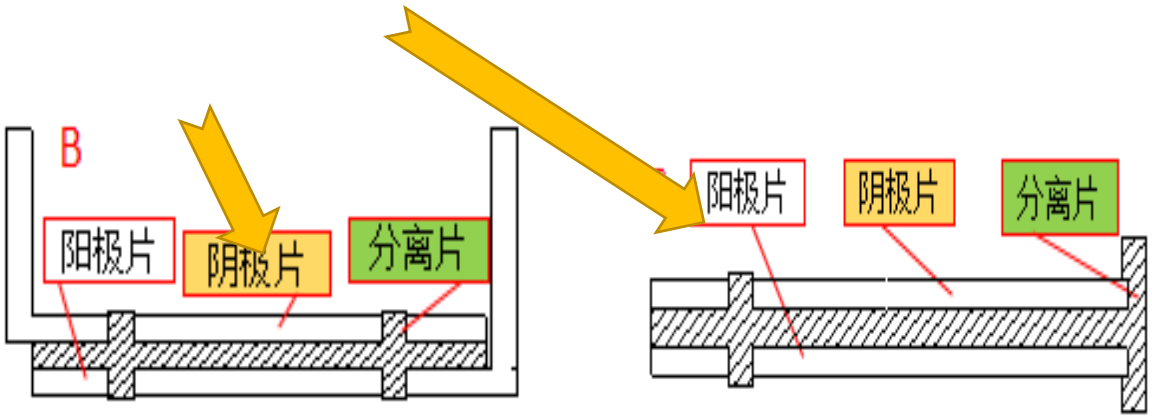


图 6

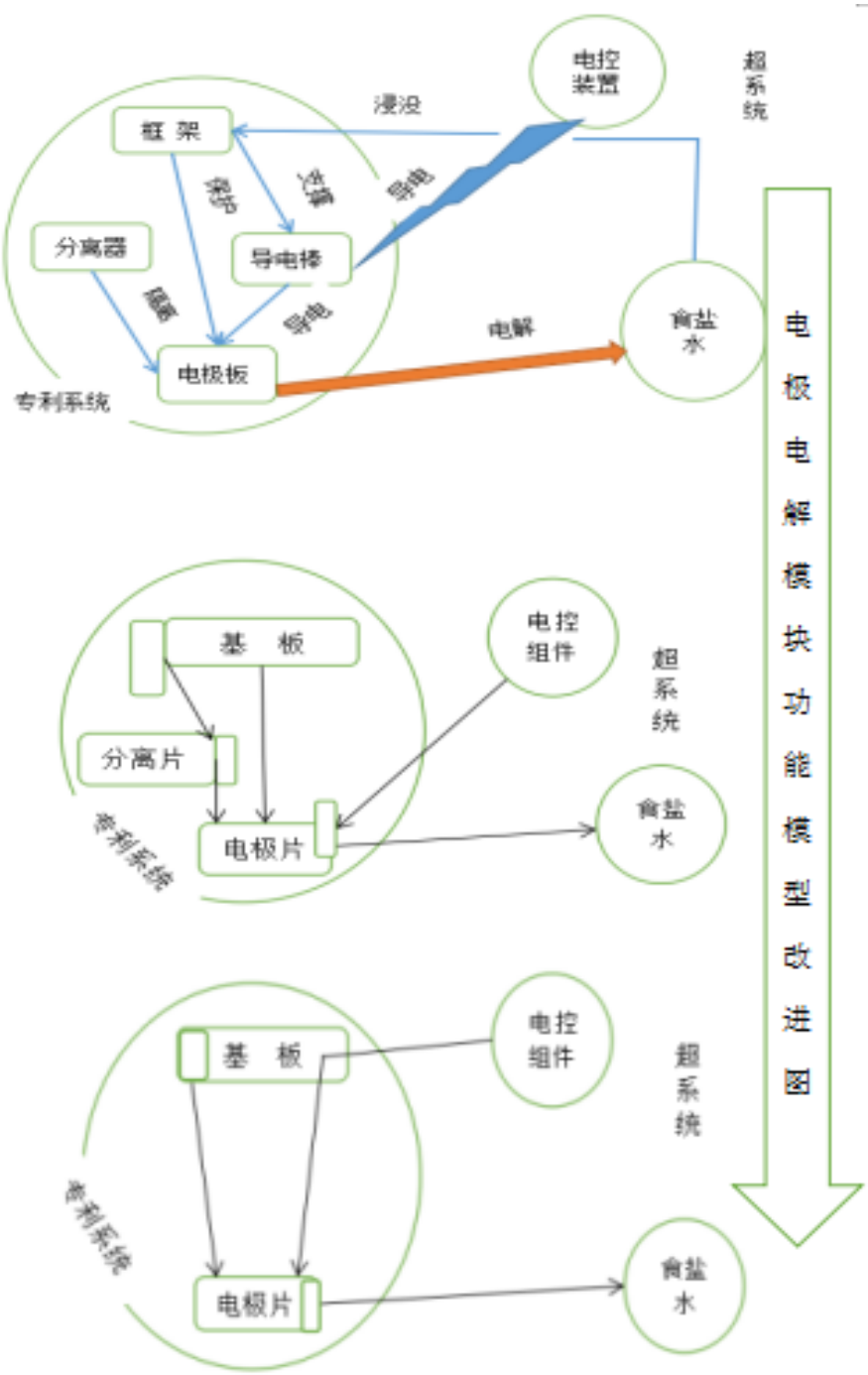


图 7

又以本项目一款消毒喷壶为例：与对手产品相比，已精减近 2/3 的零件,见下图 8,其中最上方为目标专利和对手产品的电解装置,余下 3 改进方案（均已申请专利，最下方案已产品化）,在电解功能不变的前提下,愈向下的改进力度愈大,见图 9 的产品结构，见图 10 产品的电解装置。

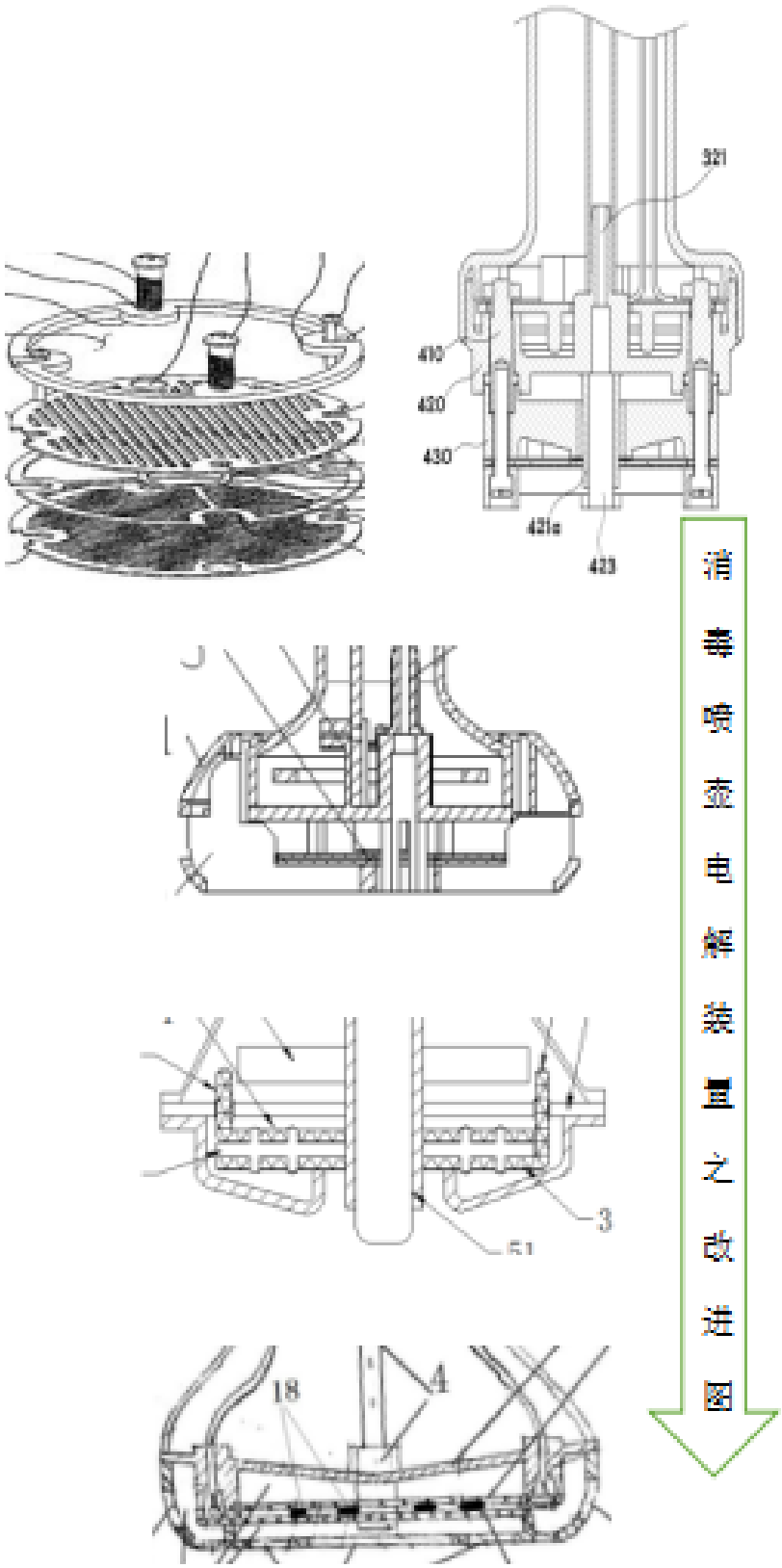


图 8

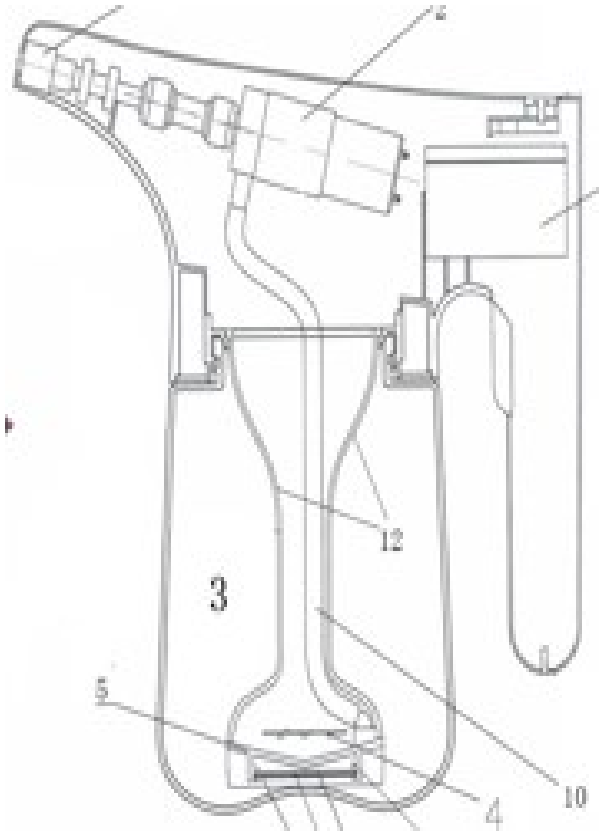


图 9

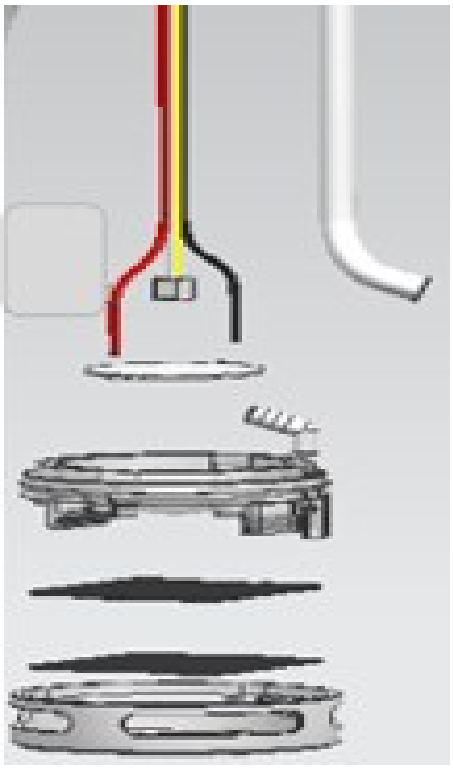


图 10

五、专利再生

依据《系统性专利规避再生与强化》理论，认为采用系统性创新方法可以从他人或自己的专利来产生更多专利和价值。为此，本项目积极利用系统化创新思维方式，不仅要规避目标专利，还要再生或强化目标专利，“希望由对手(或自己)的专利产生新专利的点子”[8]。

5.1 阶层式专利再生模式[9]

专利再生是舍弃掉原本的目标专利内容，只保留目标专利系统对标的物（对象）作用的主要/特征功能以及其带来的系统价值，因此经由专利再生得到的解答往往会跟原来的专利内容不相同，是属于一种较为积极的专利规避方法，且有很大机会可以产生新的专利。而专利再生常用手法是**裁剪**以及**替代**，共产生三类专利再生模式 ，如表 4：由于本篇幅有限，重点介绍 3-A、3-B 栏。

表 4 基于价值的阶层式专利再生模式

功能 层级	运作对象	换/改	减	再生模式	运作方法
0	价值(Value)				
1	主要功能 (Main Function)	ü	û	一	取代主要/特征功能
2	工作原理 (Action Principle)	ü	û	二	改变工作原理(达到相同功能)
3-A	目标元件(Target)	ü	û	三(A)	取代主要工具:自我服务
3-B	超系统元件 (Super Component)	ü	ü	三(B)	取代主要工具:超系统组件

其中专利再生模式 3-A (自我服务)[10] ，采用 3-A 刺激思维表格(特征功能)，如下表 5：

表 5 3-A 刺激思维表

表 5 专利再生模式 3-A (自我服务)			
特征价值	通过导电，获电能而电解	特征功能	导电
工作原理	电能流动	特征属性	导电棒输电给电极片
工具	导电棒	受件	电极片
刺激思维问句	受件(T)如何以原效应(E0)来达成 F0? 受件(T)如何以(原功能)新效应(En)来达成 F0? 受件(T)如何以其他新功能(Fn)来达成价值？ 原工具(R0)具备何种属性而能达成原功能? R0 属性如何转给受件而能达成原功能?		
原效应	E0 =传输电力	电极片如何利用电力来电解食盐水？	电极片通过导电棒而获得电力，用来电解食盐水。
原通称功能: 导 电	E1 =导 电	电极片如何从导电棒而获得电力?	电极片利用导电棒穿过其片上孔洞，让导电棒的螺纹与螺母的接触面连接为一体而获得电力。

价值:可以通电而进行电解	F1=电解	电极片如何以其新功能来达成价值	**电极片从其电解部延伸出连接部（导电功能），并让连接部穿过基板与电解电路板上导线焊接而获通电并达成电解。**
导电棒具备何种属性而能达成原功能?	具有导电能力输给电极片	原功能提供者（导线）如何传给导电棒而能达成导电功能？	电解电路板上导线（原功能提供者）与导电棒焊接，而让导电棒获导电。

上述再生的结果是电极片从其电解部延伸出连接部（即自我服务而产生导电功能），并让连接部穿过基板与电解电路板上导线焊接而获导电并可达成电解。

其中专利再生模式 3-B[11](超系统组件)，采用 3-B 刺激思维表格(特征功能)，如表 6 3-B 刺激思维表。该表 6 的结果是：让原属超系统的主控电路板上的导线直接穿过或不穿过基板与电极片上的连接部焊接（不穿过基板的要复盖防水 ABS 电阻胶）。

表 6　3-B 刺激思维表

专利再生模式三 B (超系统组件)			
特征价值	通过导电，获电能而电解	特征功能	导电
工作原理	电能流动	特征属性	导电棒输电给电极片
工具	导电棒	受件	电极片
刺激思维问句	Xn 如何执行 E0 而达成 F0? 能否引入 Rn(新资源)来达成 F0/ E0？ R0 (原资源)具备何种属性而能达成 F0？ Xn 如何提供相似属性以达成 F0 吗？		
狭超系统组件列表	主控电路板上的导线	Xn 如何执行 E0 而达成 F0?	原主控电路板上的导线被接到电解电路板上，电解电路板上导线再与导电棒螺接。
原通称功能:导电	G0　导电功能	能否引入 Rn(新资源)来达成 F0/ E0？	**可以将主控电路板上的导线直接穿过或不穿过基板与电极片上连接部焊接（不穿过基板的要复盖防水 ABS 电阻胶）。**
原资源具备何种属性	属狭超系统的主控电路板上的导线。	Xn 如何提供相似属性以达成 F0 吗？	主控电路板上的导线同样是导电体，完全可以达成 F0 。

5.2 裁剪式专利再生模式

专利再生常用手法还有是**裁剪为主**以及替代为辅的模式，本项目应用了 A、X、B、C、D、E 六种专利裁剪模式[12] ，由于本篇幅有限，重点介绍 A、C、E 三种专利裁剪模式。

专利裁剪模式 A：功能接受者导电螺柱若被删除,表示功能提供者所提供的供电功能已无需要，即可剪去功能提供者--电解电路板，如下图 11。

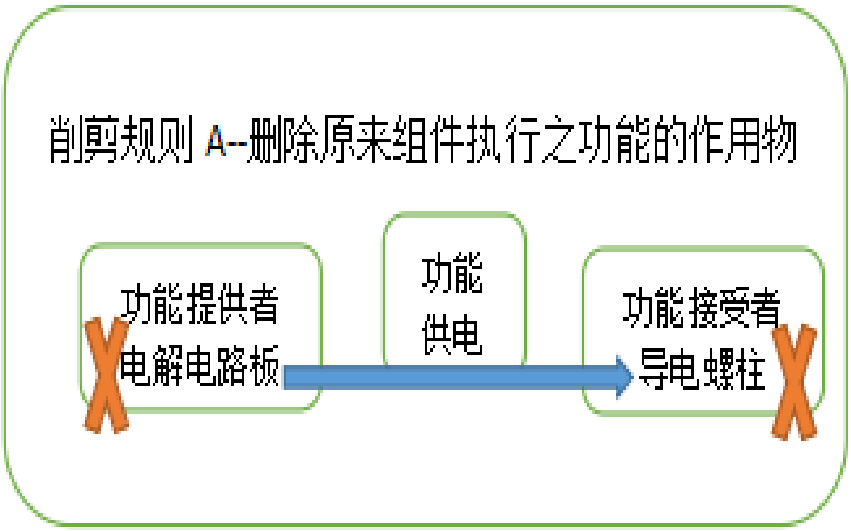


图 11

削剪规则 C: 原组件执行功能(导电螺柱--导电)由系统外组件---主控电路板导线执行，如下图 12。

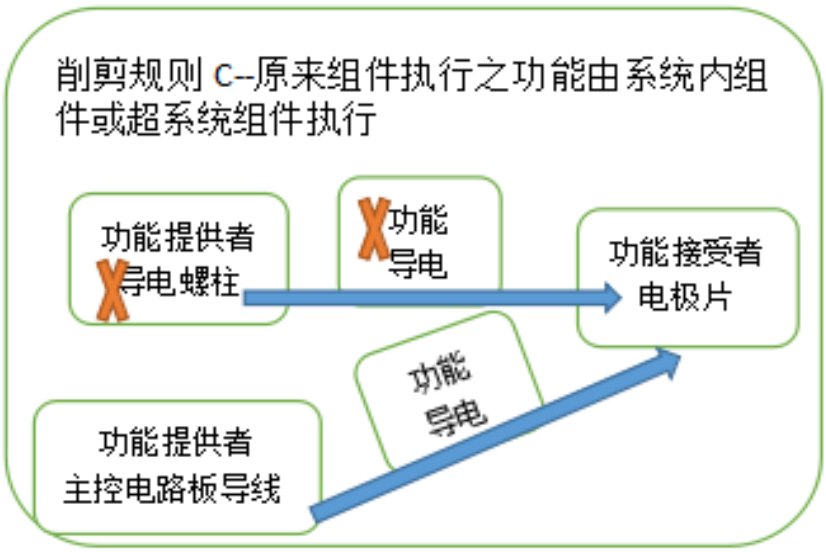


图 12

削剪规则 E：找另一个原来系统内外不存在的组件(ABS 胶滴)替代原功能提供者(分离片)来分隔阴、阳电极片，如下图 13。

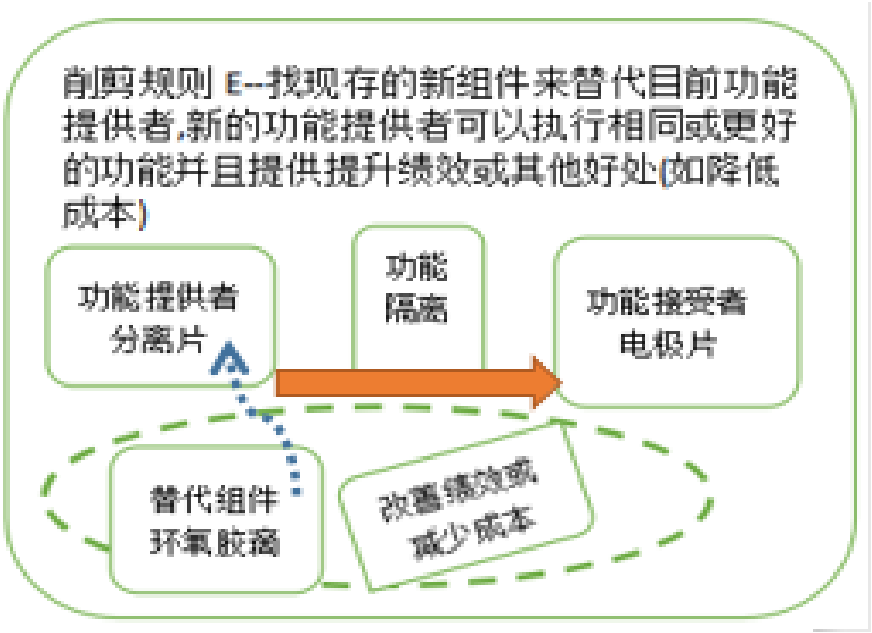


图 13

六、专利强化

根据《系统性专利规避再生与强化》理论，所述的专利强化[13]是以现有的目标专利为主，对当前专利事先考虑所有可能的强化及规避方式在现有的专利基础下，是否可以再增加一些功能/价值或增加组件的方式，让现有的专利可以变得更加完备。专利强化的应用之时机有以下两点：

（1）对自己专利强化：**本身已有独立专利构想或由规避他人专利或对他人专利再生而产生专利时，希望取得更强专利**；避免他人规避我的专利，自己先自我规避，然后把可规避的漏洞补起来，让他人无法规避我的专利；避免将来被他人专利所包围，而失去独享权益或改善产品之权益。

（2）对他人专利强化：利用别人专利，强化以包围该专利，以取得交换授权的筹码。

本项目着重是对自己改进方案或专利构想进行强化，也就是在上述电解装置改进或专利设想基础上进行专利强化的。

在现有的《系统性专利规避再生与强化》理论中，利用专利强化来提升产品的整体价值共有二种模式：一是演化趋势法，主要应用工具是演化趋势问答表格（共 54 栏）[14]；二是关联系统扩张法[15]，其中包括正系统扩张、反系统扩张以及以 CPC 产品导向的扩张（CPC 三位扩张）。

6.1.演化趋势法应用

利用 TRIZ 的演化趋势，配合演化趋势问答表格，询问该目标专利价值、功能、属性可否用此演化趋势进行强化和再生，并说明演化至第几阶段（红字）；从专利强化来看，对拟申请专利（方案）或产品对照演化趋势找出系统进化的方向。见下表 7：表中想法栏位置偏小（暂空白），只能用后续图 14、图 15 实例说明。

表 7　演化趋势问答表格			
专利名称:{填入专利名称}			
		主要功能	特征功能
功能		电解水	电解食盐水
受件(目标物)		水	食盐水
运作原理		电化学反应	盐水电解反应
价值		产生氢、氧气	产生氢气、次氯酸钠等
工具		电解装置	盐水电解装置
属性		{工具，受件或功能的特征属性}	{工具，受件或功能的特征属性}
No	趋势名称	演化阶段	想　法
2	装置削减	复杂系统→消除子系统组件→消除非关键组件→消除非关键次系统→削减后系统	
3	增加组件的完整性	工作件→传动件→能源→控制系统	
4	单双多-增加差异	相似组件(同质)→有差异的组件→反系统的组件→竞争系统/不同组件	
5	增加不同的功能	单系统→竞争系统→联盟系统→异种系统→反系统	
6	深度整合	未链接→先后连接→部分削减系统→完全削减系统	
7	增加相似整合性系统	单系统→双系统→多系统	
8	增加相异整合性系统	单系统→双系统→多系统	
24	从巨观到微观	较宏观→较微观	
30	向下展开	非阶层式结构→二阶结构→三阶结构→递归架构	
33	向上整合	独立结构→与较高层结构结合→完全与较高层结构整合	
37	增加透明	不透明→部分透明→全部透明→主动透明组件	

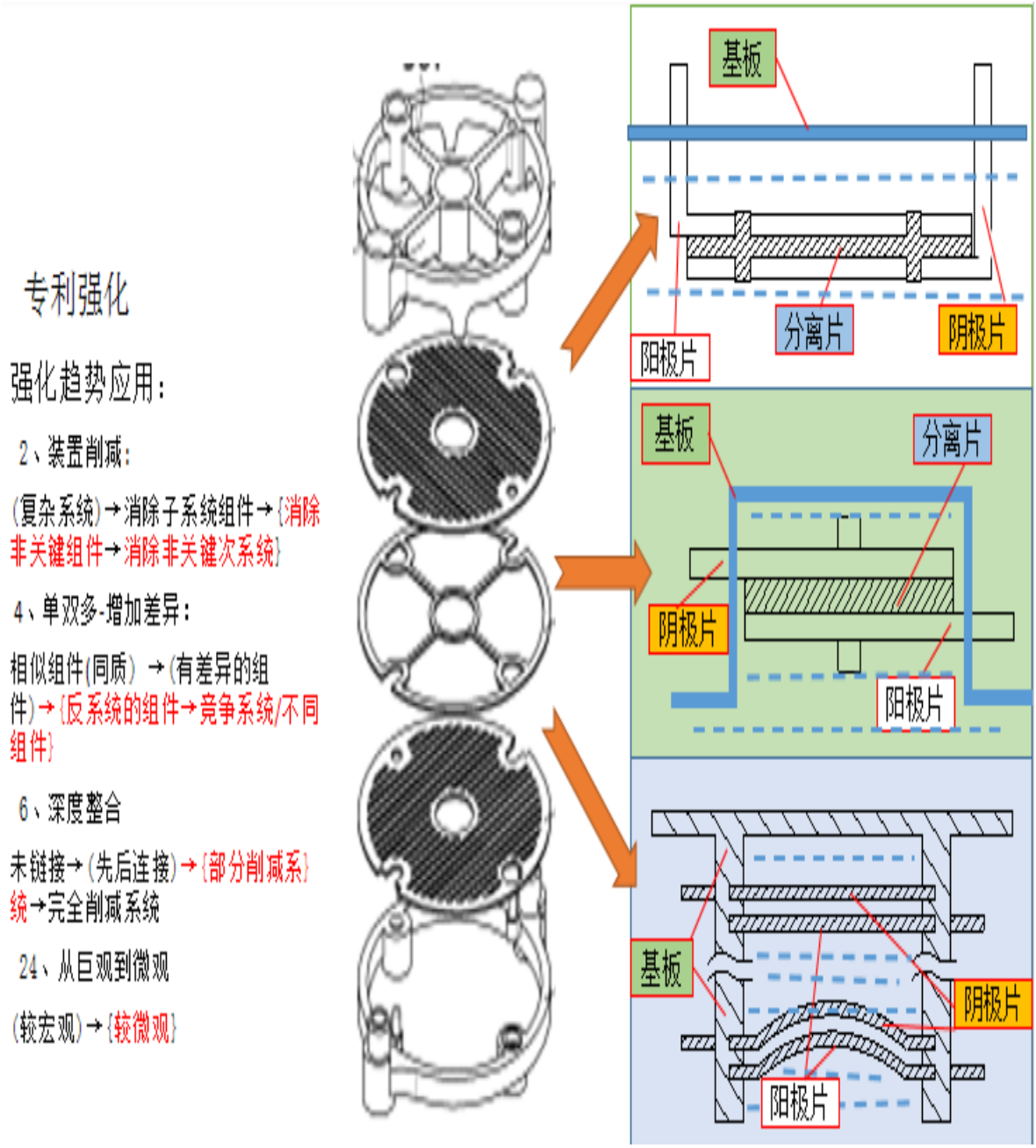


图 14

例 1：对目标专利进行再生和规避后，有的构想还需要改善和强化，其中应用强化趋势有 2、4、6、24 等，可形成如上例中至少三种电解装置，为后续产品方案打开思路，如图 15，将不同结构电解装置结合在相适应的容器，形成崭新产品方案。

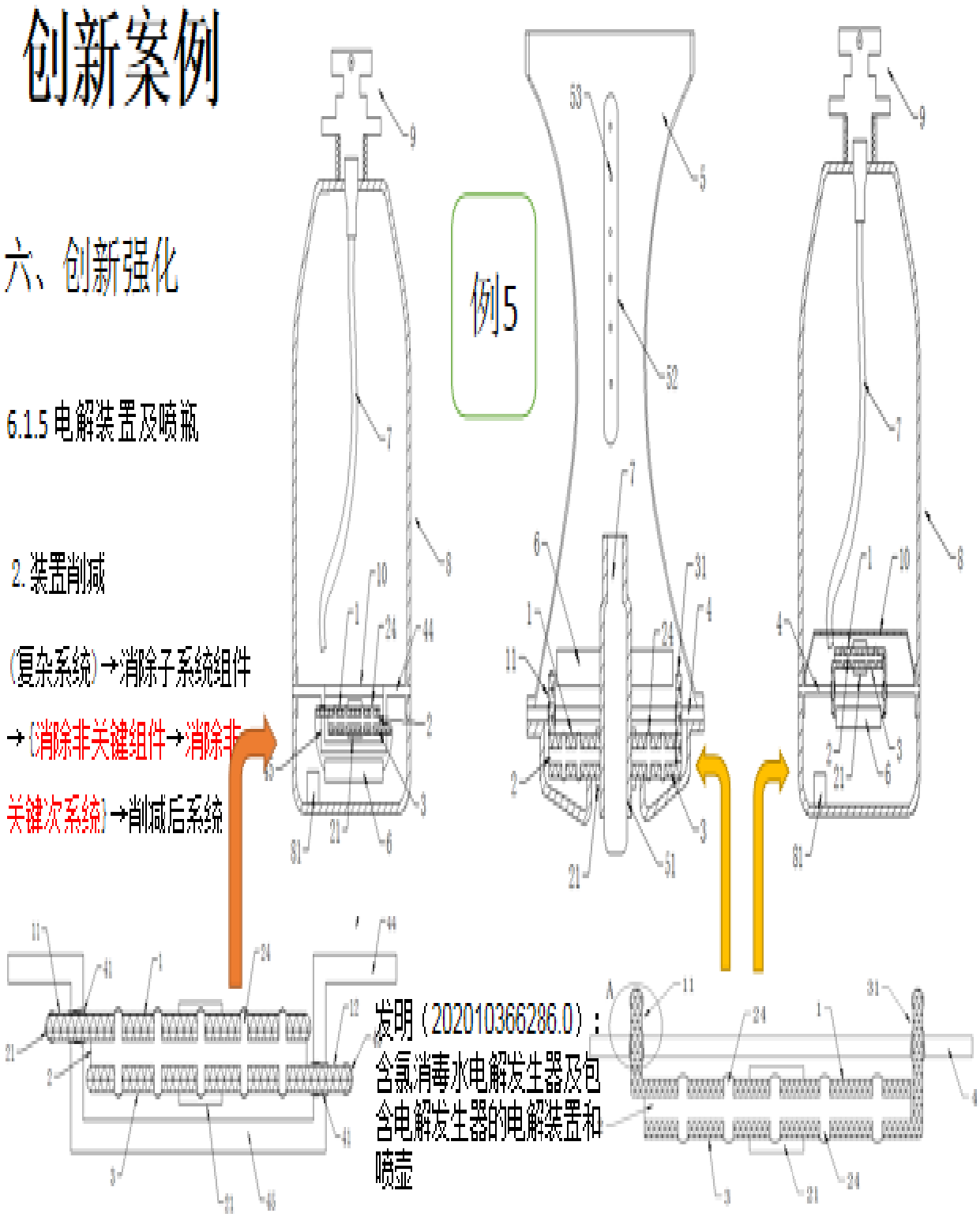

创新案例
六、创新强化
例5
• 6.1.5 电解装置及喷瓶
•
• 2. 装置削减
• (复杂系统)→消除子系统组件
→(消除非关键组件→消除非关键次系统)→削减后系统
说明(202010366286.0)：含氯消毒水电解发生器及包含电解发生器的电解装置和喷壶

图 15

6.2 关联系统扩张法应用

专利强化中的关联系统扩张法，在本案应用到包括正系统扩张，如表 8；如反系统扩张，如表 9。本项目实施中，《基于 TRIZ 的关联系统扩张的双柄消毒喷枪及其设计方法》[16]（申请号：202010368156.0），见图 16。该发明专利是较为典型应用实例。

表 8　正系统扩张法

<table>
<tr><td colspan="2" rowspan="2">系统关联法</td><td colspan="2">相同环境下</td><td>不同环境下</td></tr>
<tr><td>对象相同</td><td>对象不同</td><td></td></tr>
<tr><td rowspan="4">特定功能</td><td>功能相同</td><td>竞争系统::当 A 系统、B 系统具有相同功能与服务对象，AB 即互为竞争关系。将其各自优点结合在同一个系统当中达到创新的机会，结合成新的产品。</td><td colspan="2">准竞争系统</td></tr>
<tr><td>功能不同</td><td colspan="2">情境系统:在本系统运作时空相同之情境下的其他系统。可将情境系统下，多数系统的功能，整合到一个系统上，因而一个系统可以同时执行多种功能，而强化该系统，减少对其他系统的需求(情境系统可视为多屏法之超系统正向扩张)。</td><td></td></tr>
<tr><td>功能互补</td><td>互补系统:在同一情境或服务对象下 A 系统、B 系统若各自执行功能，无法满足 标的物全部的需求，两者一齐工作，功能互补，可以达到一加一大于二之综效。</td><td>准互补系统：两系统对不同的作用对象提供互补的功能。</td></tr>
<tr><td>缺点或不足</td><td colspan="3">多 屏 法:以“缺点”、“不足”之角度帮助用户从时间与接口的角度进行产品创新，把“缺点”化为需求的功能。</td></tr>
<tr><td>通称功能</td><td>相同通称功能</td><td colspan="3">类推系统：：相同通称功能但特定功能不同之系统，结合此二者形成新的系统。</td></tr>
<tr><td>价值</td><td>相同价值</td><td colspan="3">同值系统：结合两同值系统成为新的系统，如此便具有备份的功能，当 A 系统无法执行功能，可由 B 系统替代执行。</td></tr>
<tr><td>资源</td><td>资源共享</td><td colspan="3">异类系统：由于具共同可用之资源，可以不用准备两份资源，可让资源产生更大效益。</td></tr>
</table>

表 9 反系统扩张法

关联系统-反系统	相反(+/-)	阻碍/破坏(-)	修正/补强(+/-)
当前功能	反系统 1 相反功能：	**反系统 2 阻碍/破坏 功能：** 能阻碍当前系统主要功能无法正常发挥之系统。	反系统 3 **修正/补强 功能：** 具有能修正当前系统主要功能不足之处的功能之系统。
系统/组件		反系统 4 破坏系统	反系统 5 **修正/补强 系统：**具有能修正补强当前系统本身弱点之系统。

表 8 的正系统扩张法中被应用有 6 个：竞争系统（电动系统与手动系统的组合）、情境系统、准互补系统、多屏法、同值系统、异类系统；应用了表 9 反系统扩张法中被应用有 3 个： 阻碍 功能（设置开关保险）、修正功能（增加水路磁化防垢，防止电极片积垢）、修正 系统（设计有单向阀排气）。经专利检索,表明这是第一次应用 TRIZ 的关联系统扩张法协助创新并形成专利申请案，且受惠于抗疫政策，走“绿色通道”，仅 36 天就提早了公开（上专利检索网可查），不到 10 个月，该发明就授权了。

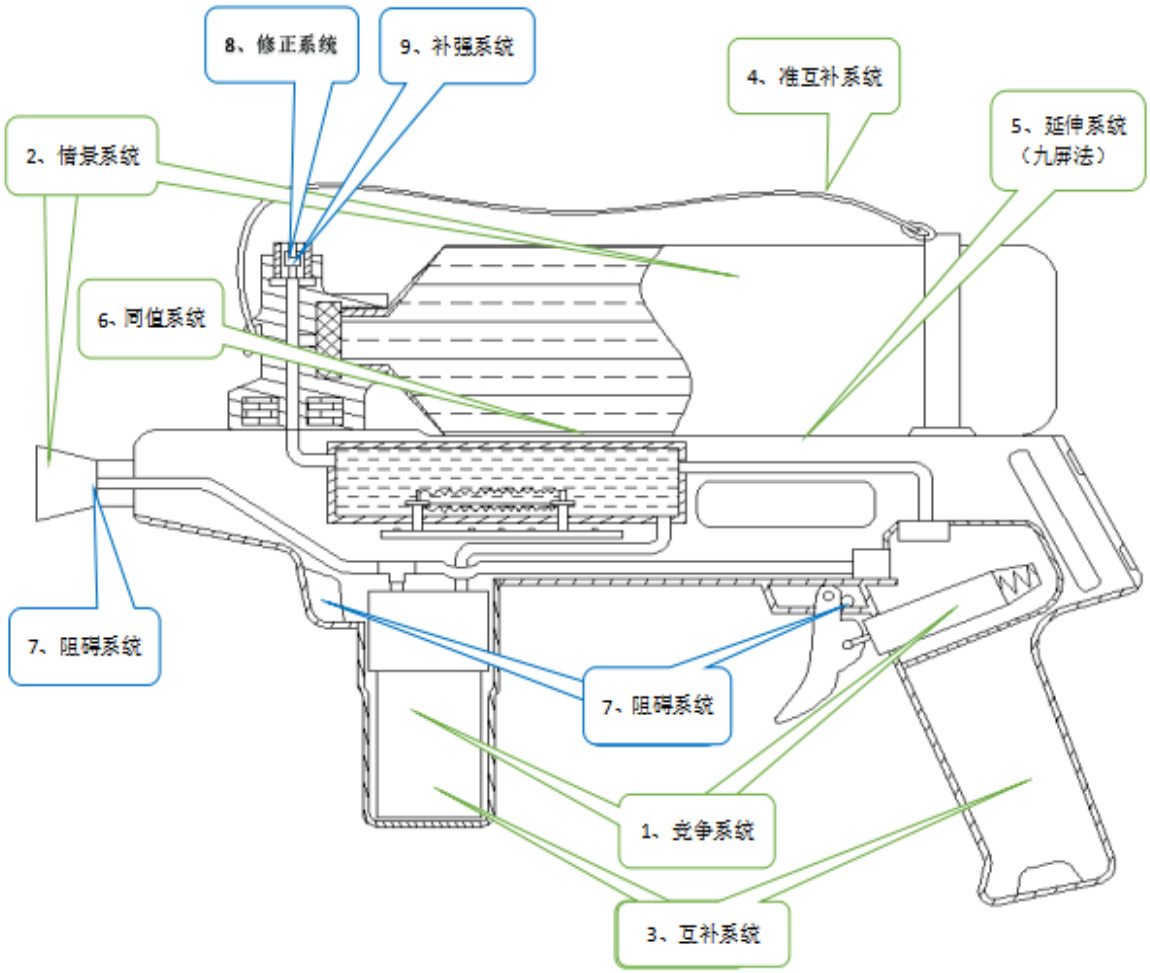


图 16

七、项目总结

自 2020 年元月起，本电解装置及产品创新的研发，由于抗疫形势所急需，得益于 TRIZ 理论方法的指导，历时数月，应用专利规避、再生与强化以及专利扩展、专利布局等 TRIZ 理论方法，突破同类现有技术围堵，已取得阶段性成果。项目期间，公司内部先后培训创新方法《系统性专利规避再生与强化》8 次 还邀请了江苏佰腾、福建元创、福州科扬 3 家专利代理服务单位加盟参与研发，还召开了有日本、韩国及中国台湾多位专家（许栋梁教授、陈佳宏博士等）参加的三次视屏会议；已成功开发出 5 种产品,总结出 3 篇技术论文，并已申请 35 件专利（已授权 16 件,其中发明 2 件[16、17]）），当年消毒喷壶产品产值达 600 多万元。为抗疫急需，是全国首家，将最新研发的消毒喷壶产品捐赠给武汉金银潭医院（武汉封城前一天）；2020 年以来，本单位与福建红十字会等配合为各地医院、学校等捐赠消毒喷壶产品价值近 60 万元人民币。

本项目经国家一级科技查新咨询单位中国化工信息中心有限公司 3 份查新报告结论:“未见其它相同或类似报道，本项目具有新颖性”。

本项目列入中国科技部创新方法工作专项（项目编号 2017IM010200），列入中国科技部创新方法与防疫专项（项目编号 2020IM010200）。

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Innovative Design of Bearings Friction Torque Testing Machine Based on EBD Methodology

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Abstract

As the problem of long-term lubrication in space has become the main restricting factor for the life of spacecraft, the study of the change of friction torque of momentum wheel bearings under long-term operating conditions is urgently needed. Based on the environment-based design (EBD) methodology, this paper establishes a design model of the friction torque measuring instrument for the momentum wheel bearing with specific research requirements, carries out a targeted conceptual design according to the actual working environment of the momentum wheel, clarifies the performance indicators of the testing machine, and then divides it into the drive module and the load module for prototype development. A test method for the calibration and measurement stages is also proposed to solve the interference conflict caused by the non-target load on the test results. This case verifies the rationality and effectiveness of environmental design theory in the innovative development of test instruments in the bearing field.

Keywords: bearings, friction torque, environment-based design methodology, innovative design.

1. Introduction

As an essential basal spare part of mechanical equipment, bearings play an important role in providing support for rotating parts, reducing rotational friction, and ensuring a certain rotation accuracy(Hwang & Lee, 2010). The performance of bearings greatly affects the stability and accuracy of mechanical equipment. High-performance precision instruments such as gyroscopes (Feng et al., 2015) and momentum wheels (Huang et al., 2020) have stricter quality requirements on bearings where bearings may be in extreme working conditions such as high-speed rotation, vacuum, or low temperature. Friction torque is a key indicator for evaluating bearing quality. Friction torque directly affects the energy consumption of rotary motion, local heating, parts wear, vibration, and noise. The temperature rise caused by friction may lead to the deterioration of lubricating grease performance and further increase friction torque (Pan et al., 2020). In some precision instruments, the friction torque of the bearing also affects the accuracy of action and information transmission (Wang et al., 2014). Therefore, it is very important to obtain the friction torque of bearings.

The design activity features changing an existing environment to a desired one by creating a new artifact into the existing environment. In the past, design relied too much on experience, and the innovation process lacked theoretical guidance, making it difficult to adapt to today's increasingly shortened design cycles and higher innovation requirements, resulting in increasing pressure on designers, especially new designers. The environment-based design (EBD) methodology is proposed to improve this situation. The basic idea is to comprehensively analyze the working environment, product structure requirements, and performance requirements of the designed product, identify conflicts and then obtain a design solution. EBD has been successfully applied in many fields. For example, Tan et al. (2012) integrated enterprise applications with EBD approaches, and Chen et al. (2019) designed a burn scar cryotherapy device based on EBD.

To verify the effectiveness of the active oil replenishment technology to improve the lubrication performance of the momentum wheel bearing, a bearing friction torque testing machine that can simulate the vacuum and radial torque loads of the momentum wheel is designed, and an applicable test method is proposed, which effectively supports the design of the bearing lubrication system based on the EBD design methodology following the process of environmental analysis, conflict identification and solution generation.

2. EBD theoretical framework

▪2.1 EBD theoretical foundation

Environment-Based Design (EBD) is a design methodology stemmed from the observation that the environment (human, natural, and built) is the foundation of every design activity (Zeng, 2011). It means that any design action changes and only changes the environment (Zeng, 2004). Design starts from the environment, functions for the environment, and brings changes to the environment. During the environment-changing process, EBD provides step-by-step procedures with three interdependent activities: environment analysis, conflict identification, and solution generation.

In EBD, the relation among designer, artifact, and environment can be illustrated in figure 1. Environment analysis is the source of obtaining design requirements. The designer's role in the design work is to analyze the hidden demand conditions behind the product's environment and formulate a draft or preliminary plan. Designers must understand and analyze environmental requirements to generate appropriate solutions to better serve their environment. (Zeng & Zhang, 2019)

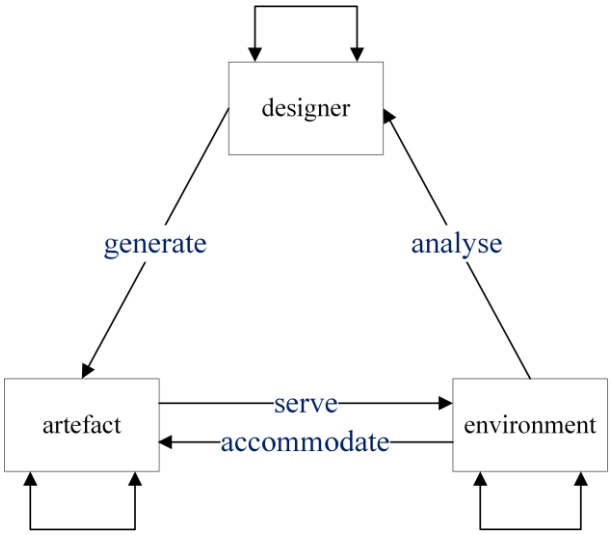
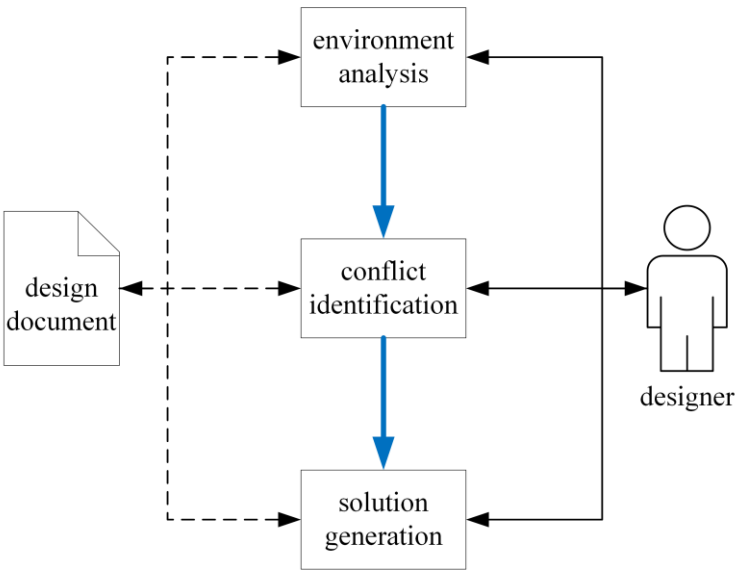


Figure 1. Environment-based design model (Zeng & Zhang, 2019)

▪2.2 EBD application process

As illustrated in figure 2, EBD believes the process of design includes three links, which are environment analysis, conflict identification, and solution generation. Through the cooperation of these three links, the designer can efficiently and recursively refine the design details and schemes. Firstly, to carry out environment analysis, one of the most effective ways is to conclude semantic analysis with the help of recursive object model (ROM) (Chen et al., 2007). ROM uses symbols of primitive objects, compound objects, constraint relations, connection relations, and predicate relations to represent the environment with a diagram. Secondly, conflicts and potential conflicts will be iteratively identified by applying rules (Zeng, 2011) to the ROM diagram. Lastly, designers will easily find the root conflicts from the former conflict identification link to generate targeted solutions and update the ROM diagram. This process will be repeated iteratively until no more unacceptable conflicts exist.



Note: The solid black lines represent the subject-verb relation, the dashed black lines represent the verb-object relation and the blue lines represent the order among three activities.

Figure 2. Process flow of EBD (Tan et al., 2012)

3. Design a Momentum Wheel Bearings Friction Torque Testing Machine based on EBD

▪3.1 Design model

In the design problem to be solved in this paper, the environmental analysis comes from the development of a bearing lubrication system based on the active oil replenishment strategy for the space momentum wheel. To understand the characteristics of the test object, the designer needs to investigate the on-orbit operating conditions of the momentum wheel, analyze the structural requirements and performance requirements of the friction torque testing machine, and target the main contradictions in each iteration design to finally complete the design of the testing machine which is verified by testing the performance of the bearing under different lubrication strategies. The design process is shown in Figure 3.

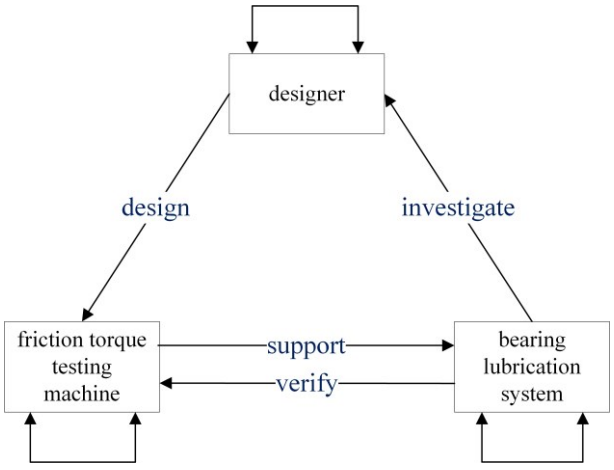


Figure 3. Friction torque testing machine design based on EBD

Based on the EBD design logic and language analysis method, the design gist of this paper for the bearing friction torque testing machine can be summarized as "design a testing machine for the momentum wheel to validate the active oil replenishment strategy by simulating the working condition", and the ROM is established as shown in figure 4. The relationship between the number analysis of each object is shown in Figure 5. The analysis found that object 2 (testing machine) has the most relations, and according to the rules for generic questions, the constraints in the

outermost ring of the relation are first asked (Wang & Zeng, 2009). After repeated inquiries and corrections, the improved ROM is shown in Figure 5.

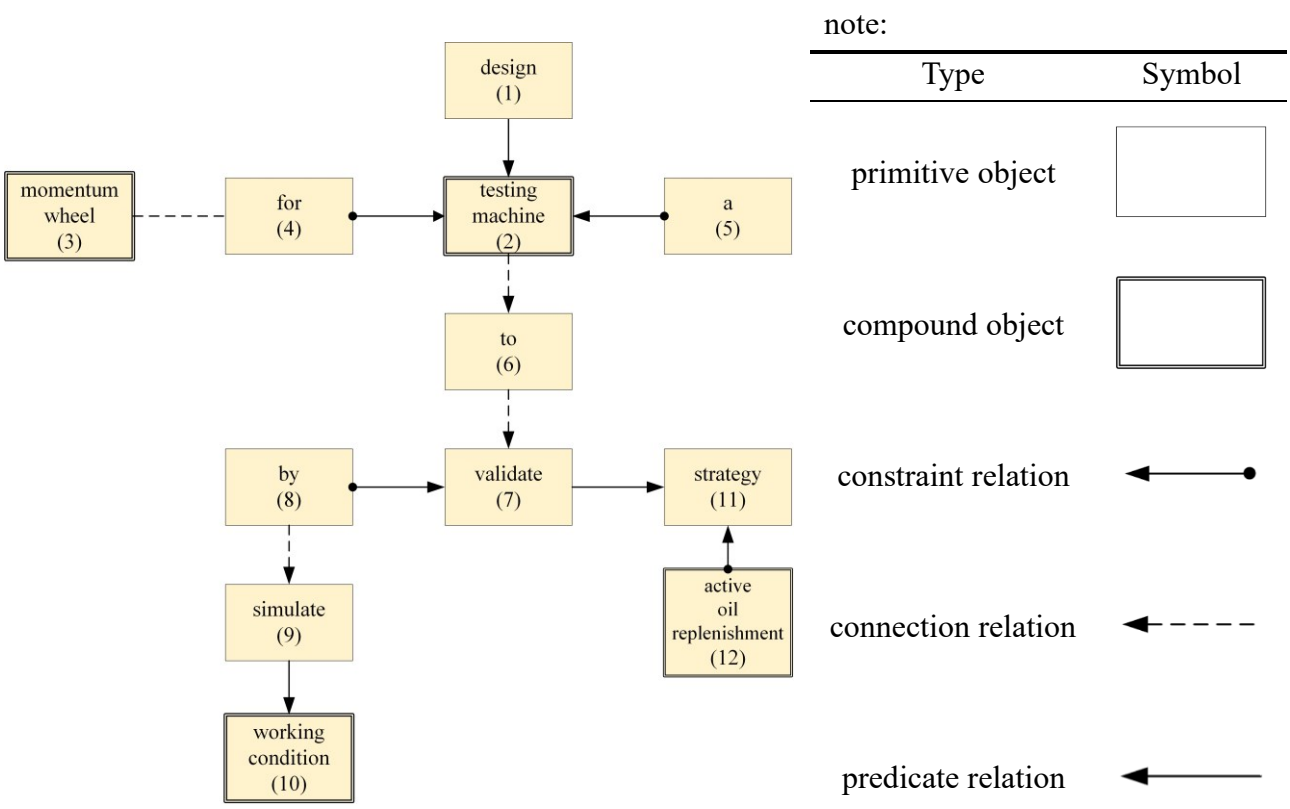


Figure 4. ROM of requirement description

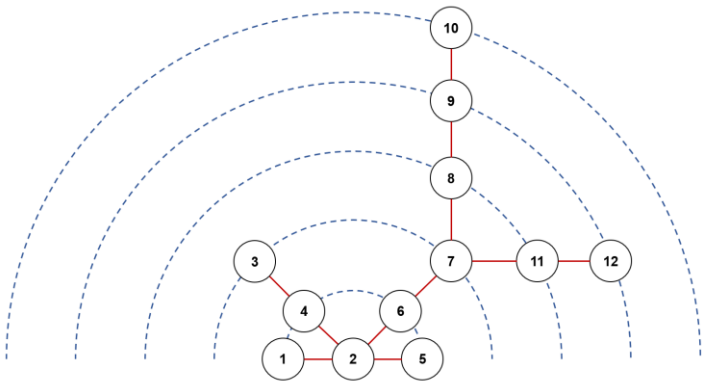


Figure 5. Relations among objects in ROM

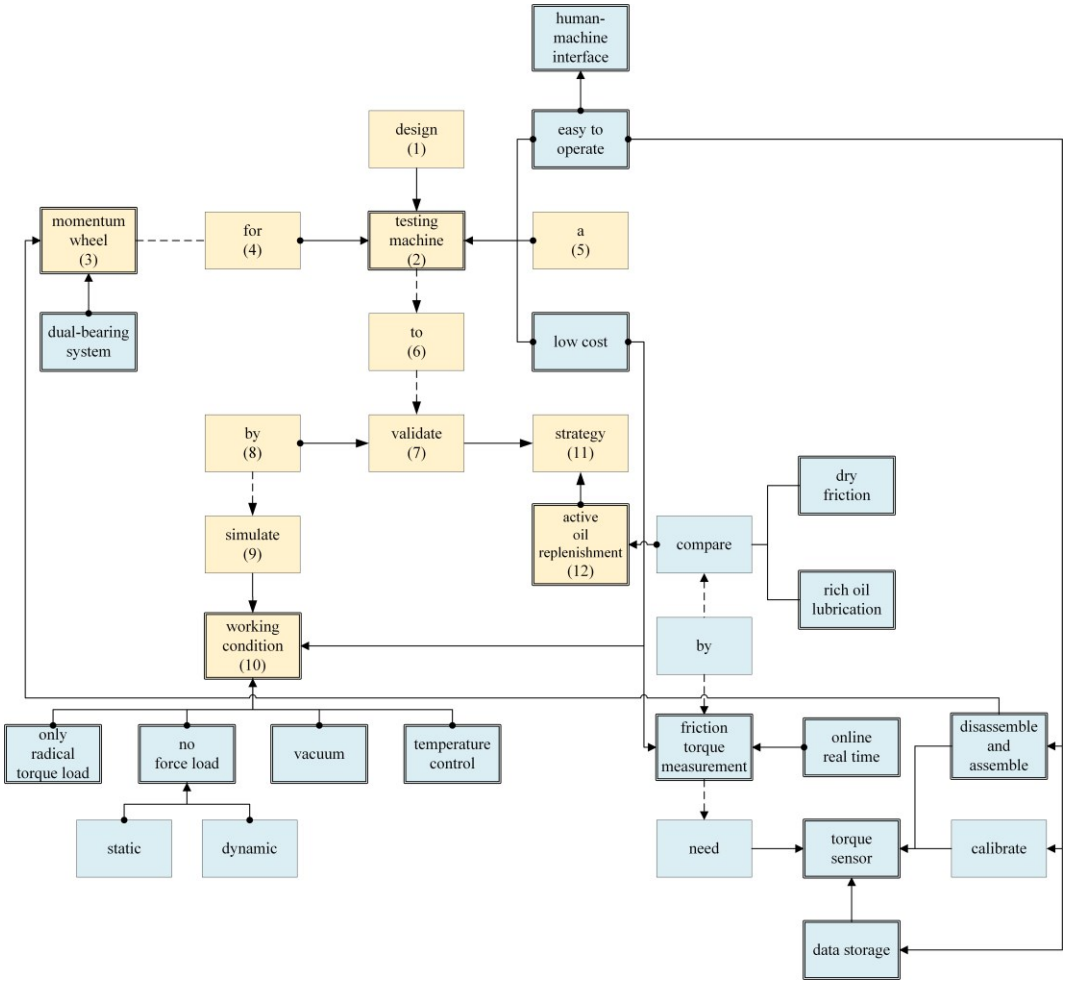
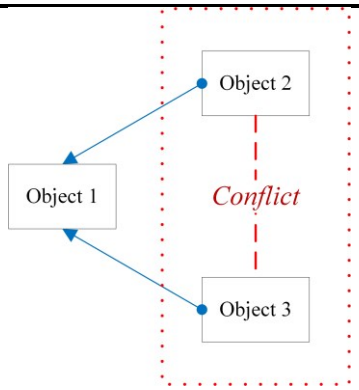


Figure 6. The updated ROM

▪3.2 Conflict identification

Table 1 shows three rules to identify potential conflicts in ROM. By applying these rules to the updated ROM, the key conflicts in the design of the bearings friction torque testing machine can be listed in Table 2.

Table 1. Three rules for identifying potential conflicts in ROM (Zeng, 2011)

Rule 1:	If an object has multiple constraints, then a potential conflict exists between any pair of constraining objects.	

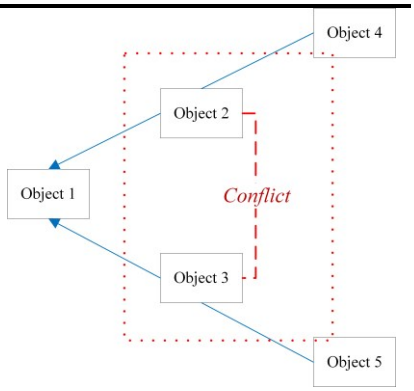
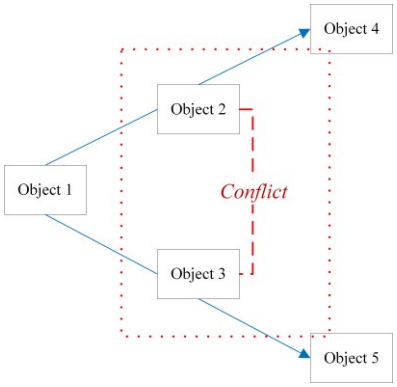
Rule 2:	If an object has multiple predicate relations from other objects, then a potential conflict exists between a pair of those predicate relations.	
Rule 3:	If an object has multiple predicate relations to other objects, then a potential conflict exists between a pair of those predicate relations.	

Table 2. Key conflicts in the design of bearings friction torque testing machine

Type	No.	Conflicts	
technical issues	1	Apply radial torque load	No force loads are introduced
	2	Apply radial torque load	Measurements may be affected by loads
human-machine issues	3	Working condition setting and data collection	Easy to operate
	4	Disassembly and assembly of the momentum wheel	Easy to operate

▪3.3 Solution generation

Conflict 1,4 Design of loading module

The design background of the loading module is that the conventional bearing friction torque testing machine loads at a single bearing instead of the bearing system by applying a force load and measuring the friction torque. However, this loading strategy does not consider the installation error of the bearing system and the error caused by the vibration during the working process. The results obtained from the test are not effectively applied to the bearing system under extreme conditions such as the satellite momentum wheel.

For conflict 1, the key to avoiding the application of force load is to avoid direct contact between the loading module and the momentum wheel, so this design divides the loading module into two parts to separately generate and transfer the load, as shown in Figure 7, the staggered arrangement of the two suspended weights produces radial torque load, and realize load transmission through the sliding pair, even if there is a force load, the sliding pair can resolve it by forward and backward and up and down movements to ensure that only radial torque load is transmitted.

Conflict 5 is a subordinate of Conflict 1. In the solution of Conflict 1, the precise fit of the sliding pair limits the movement space during the disassembly and assembly of the momentum wheel, which increases the difficulty of the operation and is contrary to the goal of being easy to operate. To cover the issue, the moving space is re-given by installing a two-degree-of-freedom sliding table in the load generation part. The in-plane motion of the load generation part realizes the disassembly and assembly of the momentum wheel while the other side is fixed to the shaft.

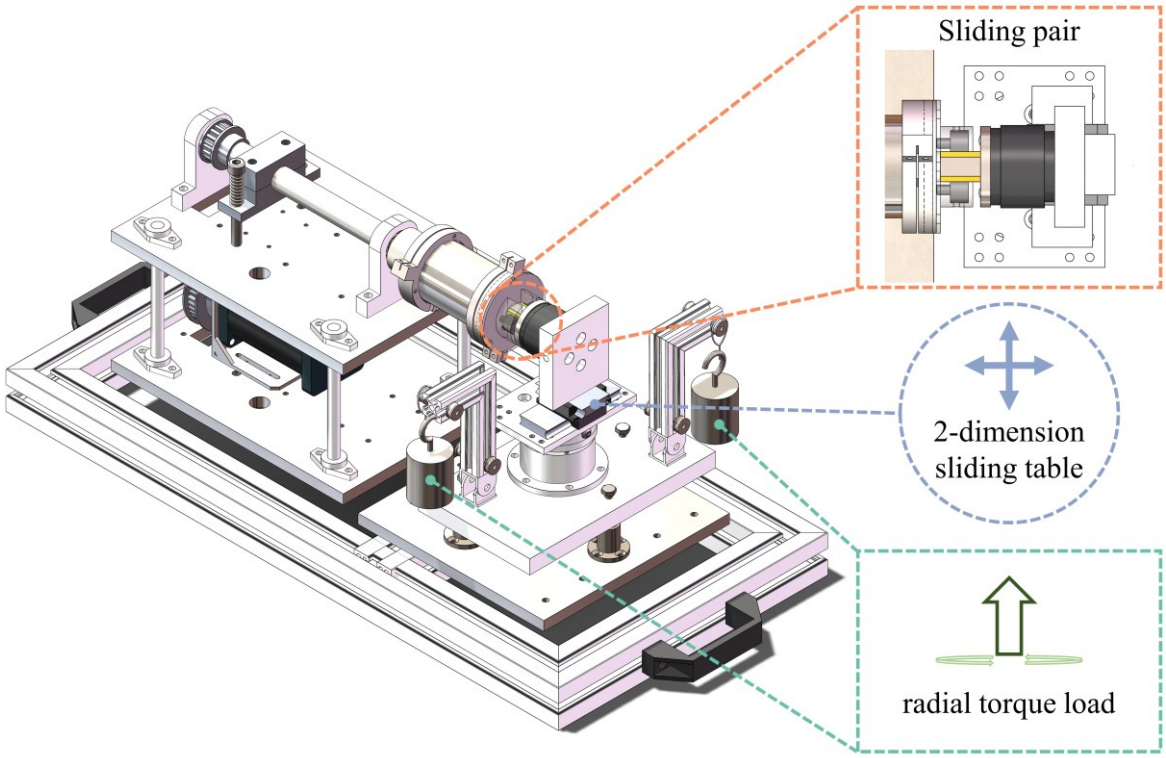
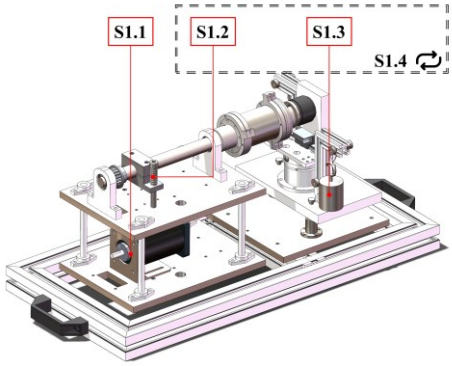
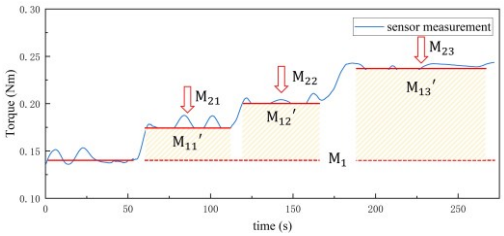
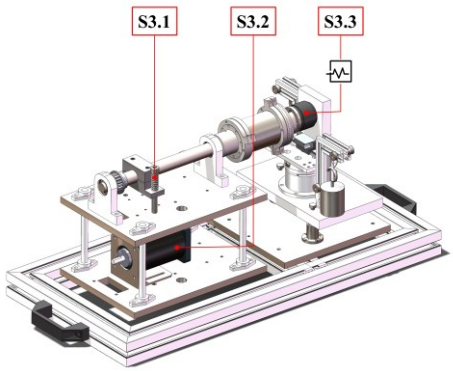


Figure 7. Design of loading module

Conflict 2 Calibration of the torque sensor

The solution of conflict 1 avoids the transmission of gravity of the momentum wheel through the sliding pair connection so that the measurement result of the torque sensor will not be biased by the force load, which is beneficial to the solution of conflict 2. Therefore, only the influence of radial torque loads on the measurement results needs to be avoided to solve conflict 2. This design resolves this conflict by designing a test method. Table 3 details the operational procedures.

Table 3. Test method for bearings friction torque testing machine

Step	Mode	Operation procedure	
S1	Calibrate mode	**S1.1** Keep the motor still **S1.2** Apply an axial torque M_1 through the spring **S1.3** Add weights to load different radial torques M_{21}, M_{22}, …M_{2n} and record current axial torques M_{11}', M_{12}', ...M_{1n}' from the sensor **S1.4** Change the axial torque M_1 and repeat S1.2 and S1.3	
S2	Data process	**S2.1** Perform the calibration according to the relation between M_1 and M_1' at different radial torque M_2	
S3	Measure mode	**S3.1** Remove the spring to avoid the additional axial torque M_1 loading **S3.2** Start the motor to rotate the momentum wheel **S3.3** Record the current radial torque M_2 and correct the axial torque of M_1' measured by the sensor to the truth value of friction torque M_1	

Conflict 3 Software development for control and data acquisition

Conflict 3 is about how to improve the operating environment of the testing machine. For the vacuum and temperature operation in the vacuum chamber, we have developed a control system that enables easy setting of the testing machine environment through the human-machine interface (HMI). For the data acquisition and analysis of the testing machine, the data acquisition and control system (DACS) was also developed. To facilitate the operation of the DACS and avoid overheating of the circuits, all circuits are arranged outside the vacuum chamber and are connected to the motors and sensors in the chamber through vacuum circuit connectors, as shown in Figure 8.

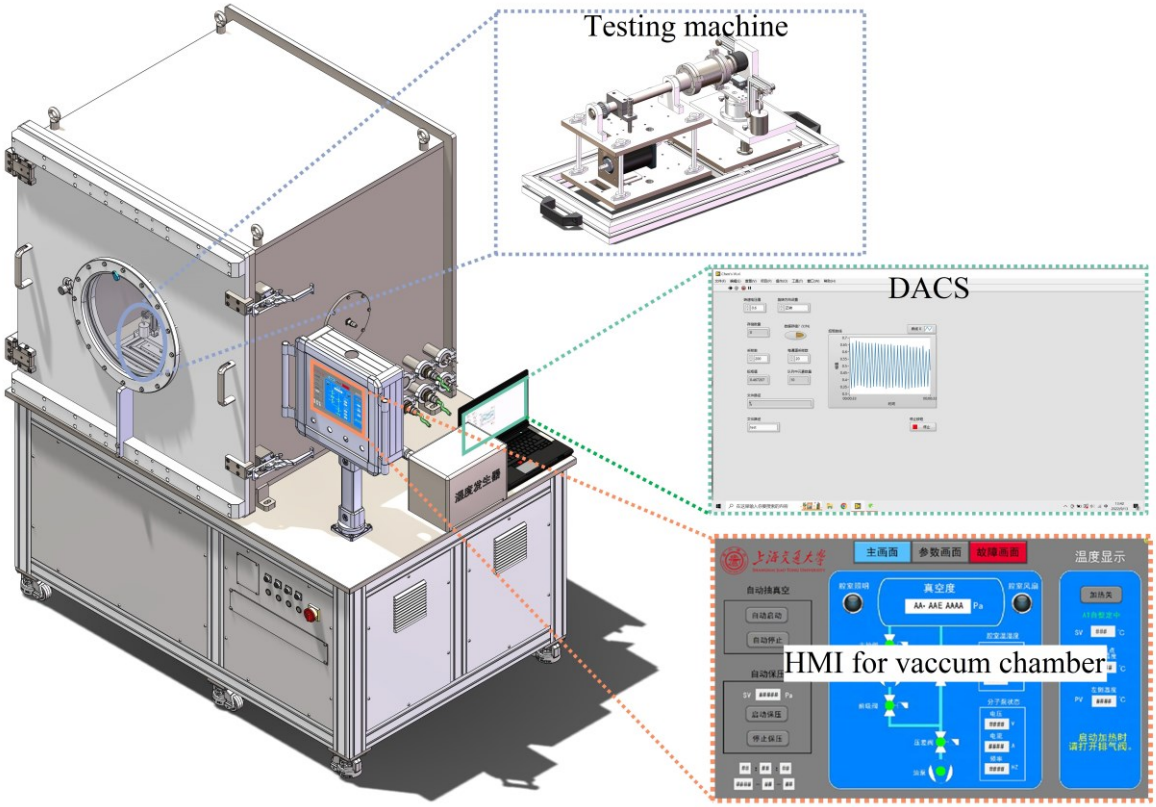


Figure 8. Software development for control and data acquisition

3.4 Design evaluation

To evaluate the generated conceptual design, this paper verifies the effectiveness of the design of the testing machine by carrying out the friction torque measurement test of the momentum wheel. Three sets of control groups, dry friction, rich oil lubrication, and active oil replenishment strategy are set up. The test conditions are the same, and the momentum wheel is set with the same preload force.

During the test, put the bearings friction torque testing machine into the vacuum chamber, then close the vacuum chamber window and start the vacuum pump. After reaching the target vacuum degree, start the flywheel drive motor and start to measure the friction torque. The test results shown in Figure 9 are consistent with the theory. At the initial moment, the friction torque of the active oil replenishment strategy test group is lower than the one of the oil-rich lubrication states. In the case of the active oil replenishment strategy, its average friction torque is close to that of rich oil lubrication and much lower than that of dry friction, when the oil supply volume is only 0.5‰ of the oil replenishment amount of rich oil lubrication. This experiment shows that the active oil replenishment strategy can effectively improve the bearing lubrication performance, and the testing machine has played its expected function.

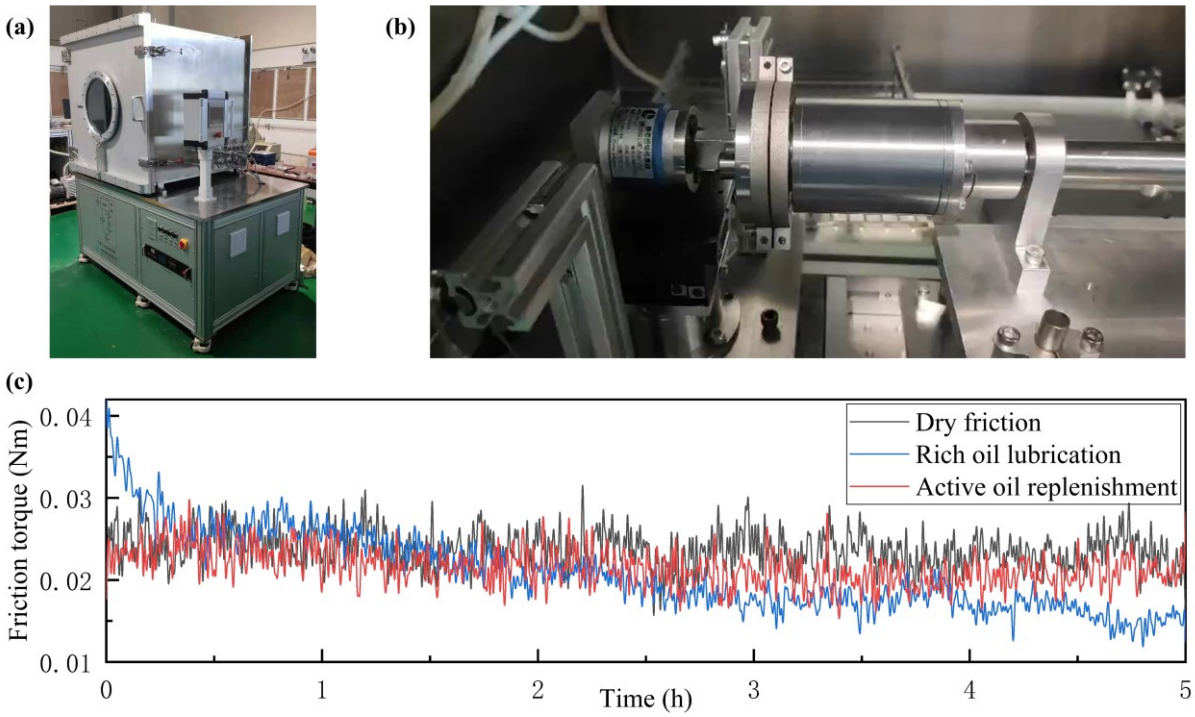


Figure 9. Friction torque measurement test of the momentum wheel

4. Conclusion

This paper analyzes the working conditions of the momentum wheel bearings and the verification requirements of the active oil replenishment strategy, excavates the key contradictions, establishes a testing machine design ROM based on the EBD theory, and realizes the generation of innovative solutions based on a rigorous and orderly process. The four key conflicts identified from the updated ROM are solved by designing the loading module, calibrating the torque sensor, and developing software for control and data acquisition. The friction torque measurement test of the momentum wheel under different lubrication states is carried out to verify the effectiveness of the testing machine design. The research results show that the environment-based design methodology is feasible in the development of test instruments in the bearing field.

Acknowledgements

This study is financially supported by the National Natural Science Foundation of China (Grant No. 51875343,12072191) and the State Key Laboratory of Mechanical System and Vibration Project (Nos. MSVZD201912, MSVZD202108).

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Topical areas (Select from listed topics on Call For Papers):

2.2 Non-TRIZ based systematic Innovation

A Systematic Approach for Requirements Analysis in New Product Design

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Abstract

A successful new product development depends on accurate and comprehensive requirement analysis. Researchers both from academia and industry have proposed numerous methods and frameworks for analyzing customers' demands. However, there still lacks a systematic approach for taking all stakeholders and environmental factors into consideration. This paper aims at developing a systematic approach for the analysis of requirements based on a step-by-step procedure. The procedure focuses on four aspects, i.e., environment, users and customers, scenario, and the benchmarking of similar products. The detailed process of each aspect is also developed. An illustrative case is given to show how to implement the systematic approach for requirement analysis.

Keywords: product design, conceptual design, requirement analysis, scenario.

1. Introduction

Requirements identification and analysis play an important role in new product design and development, especially during the early stages of the product design process. Researchers both from academia and industry have proposed numerous methods and frameworks for understanding, capturing, and analyzing customers' requirements e.g. in the generic product development model (Ulrich and Eppinger, 2012) and the systematic engineering design process (Pahl et al., 2007; Dieter and Schmidt 2021) and the function-behavior-structure design model (Gero, 2004). These methods and frameworks have provided guides for requirements analysis from different aspects, e.g., capturing requirements from customers' voices and comments on products via the online trading platform. However, requirements for product design come from different aspects, to the best of our knowledge,

there still lacks a systematic approach for taking all stakeholders and environmental factors into consideration.

Literature investigation shows interviews, workshops, and questionnaires are the traditional approaches for data collection. In general, large enterprises prefer to take the form of offline interviews or group brainstorming to collect relevant data on customer requirements in the early stage of the product development cycle (Jansen, 2008; Anderson, 2014). Due to the capacity limitation, most SMEs (Small Medium Enterprise) tend to use questionaries with lower cost instead. With the continuous iteration of products, customer requirements today are tending to be more diversified. The traditional data collection approaches often struggle to process the distributed information sources and accurately mine core customer requirements and attributes from them (Groves, 2006). Instead, more and more enterprises are adopting data-driven approaches such as semantic analysis or word frequency statistics as alternatives. The advantages of these data-driven approaches are mainly reflected in: the ability to process larger volumes of data(Jones et al., 2004), reduction in the cost of the project (Ramasamy and Selladurai, 2004), minimizing the subjectivity of the analysis (Qi et al., 2016) and etc.

Kano and QFD have commonly used approaches for requirements identification and mapping. The Kano model was first proposed by Kano (1984) to provide a basis for the subsequent conceptual design and functional design phases. Kano's model establishes a non-linear relationship between customer requirements and user satisfaction through classifying and investigating product attributes. In the Kano model, product attributes are usually classified into five categories including attractive attribute (A), one-dimensional attribute (P), indifferent attribute (I), must-be attribute (M) and reverse attribute (R). The attractive attribute represents the product attribute that may significantly increase customer satisfaction, while the lack of such attribute would not influence customer satisfaction. The one-dimensional attribute is positively correlated with customer satisfaction, which indicates that the presence or lack of such an attribute may directly lead to the increase or decrease in customer satisfaction. Indifferent attribute represents the redundant feature of a product, the presence or lack of which would have no impact on customer satisfaction. The must-be attribute represents the basic requirement of customers for a product, the lack of which would significantly decrease customer satisfaction while no impact would be caused if a product has the such attribute. The reverse attribute is negatively correlated with customer satisfaction, which may significantly decrease when the product provides such attributes and increase when it does not. Over decades of development, the Kano approach is now not only limited to requirements analysis itself but is often combined with other analysis approaches or data-driven tools and extended to each phase of the early product development cycle. Qi et al.(2016) proposed a product attribute analysis approach that combined the traditional Kano model with conjoint analysis to improve product strategies at an early stage. Compared with the traditional Kano model, such an analysis approach can ensure the reliability and helpfulness of the collected data and is more suitable for requirement analysis in a big data environment. Lee et al.(2022) proposed an analysis framework called I-Kano analysis to identify the dual importance and Kano attributes at the same time with the aid of semantic analysis and word frequency analysis. Such an

approach can help products to achieve more accurate market segmentation and positioning in the early stages. Bigorra and Karlberg (2019) proposed an approach to automatically process and classify collected product data into Kano-type attributes with the aid of sentiment analysis. It is noted that such an approach is only based on three basic Kano attributes and excludes the indifferent attribute and reverse attribute. Although the Kano model is now widely used as an important tool for requirements analysis in the early stages of the product development cycle, some scholars point out that the Kano method, as an offline method, cannot capture the real-time changes in product requirements and thus may affect the effectiveness of the requirement analysis (Green and Srinivasan, 1990). Besides, the subjectivity of the Kano model's input data and the limited attribute classification may also influence the accuracy of the analysis.

QFD (Quality Function Deployment) is another common way of requirement identification. The main objective of QFD is to effectively transform the collected customer requirements into product function in the development cycle and to further improve customer satisfaction and reduce development costs (Herrmann et al., 2006). For decades, QFD has been applied to the development process of a wide range of products and has proven to be effective (Sharma et al., 2008). Given the limitations of a single approach, QFD is often combined with other analytical methods such as AD (Axiomatic Design) theory, AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution), and FMEA(Failure Mode Effects Analysis) to improve the accuracy and completeness of requirements identification and mapping (Carnevalli and Miguel, 2008). Zhang et al. (2019) proposed a QFD-based approach to analyze and allocate weight to the collected Kansei requirement of products. The original HOQ (House of Quality) in QFD is optimized and transformed into a design matrix to further calculate the coupling degree and evaluate the rationality of each requirement. Carnevalli and Miguel (2010) proposed an approach that combined the QFD approach with AD theory to eliminate the difficulties in QFD's use to a great extent. It is indicated in their work that the mapping process of the customer domain usually determines the accuracy of subsequent domains, while not all of the CAs (Customer Attributes) can be fulfilled at this stage. In addition to combing with other approaches, various extended QFD methods have been developed to facilitate the requirement analysis. Fazeli and Peng (2021) proposed BWM-QFD and FUCOM-QFD approaches to simplify the traditional data input process and minimize the inconsistency problem to a great extent. The proposed approaches were then applied to a design case of a rehabilitation device to verify the efficiency. As QFD method has reflected its advantages through numerous practical cases over decades, such as shortening the product development cycle (Ramasamy and Selladurai, 2004), improving customer satisfaction (Akao and Mazur, 2003), minimizing project development mistakes (Ramasamy and Selladurai, 2004), etc, researchers point out that QFD still has inevitable limitations in some aspects of requirement analysis, which include: the subjectivity of the model input (Karsak, 2004), limitation in processing large volume data (Zhang et al., 2019), etc. Based on the above issues, the QFD approach would tend to combine more with data-driven tools in the future to improve the efficiency and accuracy of requirement identification and mapping.

This paper aims at developing a comprehensive framework for identifying design requirements. The focuses are on four kinds of resources for requirements, i.e. users, environments, markets, and using scenarios.

2. Framework development

Understanding customer needs and identifying design requirements is a crucial step in the product development process, especially during the early stages of the product development process, because the cost of design changes will increase dramatically if they are not implemented early (Abts and Schaudt, 2015). Although, classical engineering design books have suggested key steps for requirements analysis. However, it still need further efforts for a better understanding and analysis requirements. As for requirements analysis, Zeng and co-workers proposed an environment-based approach, which can help the designers to better understand the requirements of customers(Zeng, 2004, 2008). The basic idea of EBD (Zeng 2011, Sun et al. 2011) is that a design problem is implied in a product system and is composed of three parts: the environment in which the designed product is expected to work, the requirements for product structure, and the requirements on the performance of the designed product.

Based on the literature investigation, four sources of design requirements are identified as follows.

1) Users analysis. To analyze the users who use the product and the customers who will pay the bill.
2) Environment analysis. To analyze the natural and social standards the product has to meet.
3) Scenario analysis. To describe how the users use the product in different scenarios.
4) Market analysis. To analyze the function and performance of similar or competitor's products for clarifying the special of the product.

Based on the four kinds of sources for design requirements analysis. This paper proposes a systematic approach for the requirement analysis based on a step-by-step procedure. The procedure focuses on four aspects user, environment, scenario, and market. In the next section, the stroller is taken as an illustrative case to show the details of how to use the proposed framework.

3. Illustrative Case

As a crucial step in product development, the objective of requirement analysis is to ensure the accuracy and completeness of function implementation. In the traditional design process, requirement analysis usually tends to focus on a single factor and is performed isolatedly. This may lead to inaccuracy and uncertainty in the subsequent function identification and further affects every step of the product development cycle.

3.1 User Analysis

For strollers, both the baby and the operator (guardian) are users. The riding requirements of the baby and the operating requirements of the guardian need to be discussed separately in the user analysis.

For baby-oriented user analysis, it is necessary to take into account all the possible posture requirements that the baby may have in the car, including lying, sitting, leaning, etc. On this basis, the subsequent functional design should ensure the safety and comfort of the baby in different postures. The number is another requirement to consider, the stroller needs to have sufficient space and switch mode to be suitable for both single or twins.

Operator-oriented user analysis needs to take into account all the guardian's possible operation modes of the stroller such as pushing, running, carrying, etc. For different groups of guardians, such as parents or elders, the implementation of the operation needs to be further subdivided to ensure the reliability and convenience of the stroller for a wide range of operators.

3.1 Environment Analysis

The environment analysis of stroller products needs to start from both the natural and social environment to ensure that the subsequent functional design can meet the various needs under different environmental conditions. In particular, the natural environment analysis should be broken down into various natural conditions, such as sunshine, cold wind, rain, and snow. The subsequent functional design should address the above requirements to make the stroller with the corresponding shading, waterproof and windproof functions.

From another aspect, the environment analysis also needs to consider the social environment where the stroller may be used, such as shopping malls, streets, and homes, to provide a basis for further functional design.

3.2 Scenario Analysis

The significance of scenario analysis, which is more related to both environment analysis and user analysis mentioned above, is to correlate with different usage scenarios of the user’s daily life to make the overall requirement analysis more accurate and the product more adaptable to different environments. Scenarios should be refined to create a typical user activity map at this stage.

For strollers, the scenario analysis should be first refined into three typical user activities: using, storing, and carrying. Based on this, the scenarios are then broken down for each type of activity. Typical scenarios for stroller use include road, pavement, forest paths, etc. Storage scenarios include house or apartment, etc. And the carrying scenarios include common transportation such as buses,

trains, and private cars. Further, the scenarios above can be refined into sub-scenarios with specific characteristics, such as crossing potholes in a forest path, going up and down stairs in an apartment, etc. Such scenario refining should be continued until the scenario characteristics cannot be further refined. Comprehensive scenario analysis can provide reference and guide the subsequent functional design sessions.

3.3 Market Analysis

The main purpose of market analysis is to help the product better position itself in the market, reflect the core value and make the product more competitive. Specifically, it can be divided into market segmentation, competitive analysis, and feature analysis. For the stroller, the market analysis should start with product positioning and segment the stroller market based on different environments and target customers, and specify the similarities and differences of customer requirements in each type of market.

On this basis, competitive analysis should analyze the typical products or patents in each segmented market to determine their core competitiveness and advantages. It should be noted that data-driven tools can be well used at this stage to significantly improve the accuracy and efficiency of the analysis. For example, automated word frequency statistics and customer sentiment analysis can provide quantitative references for subsequent design decisions.

Feature analysis focuses on decomposing, optimizing and reorganizing the features and advantages of existing products. While decomposing and extracting the advantages of similar products, reorganizing and optimizing the features based on product positioning and target customers, so as to avoid patent conflicts and help designers better carry out the subsequent idea generation and functional design process.

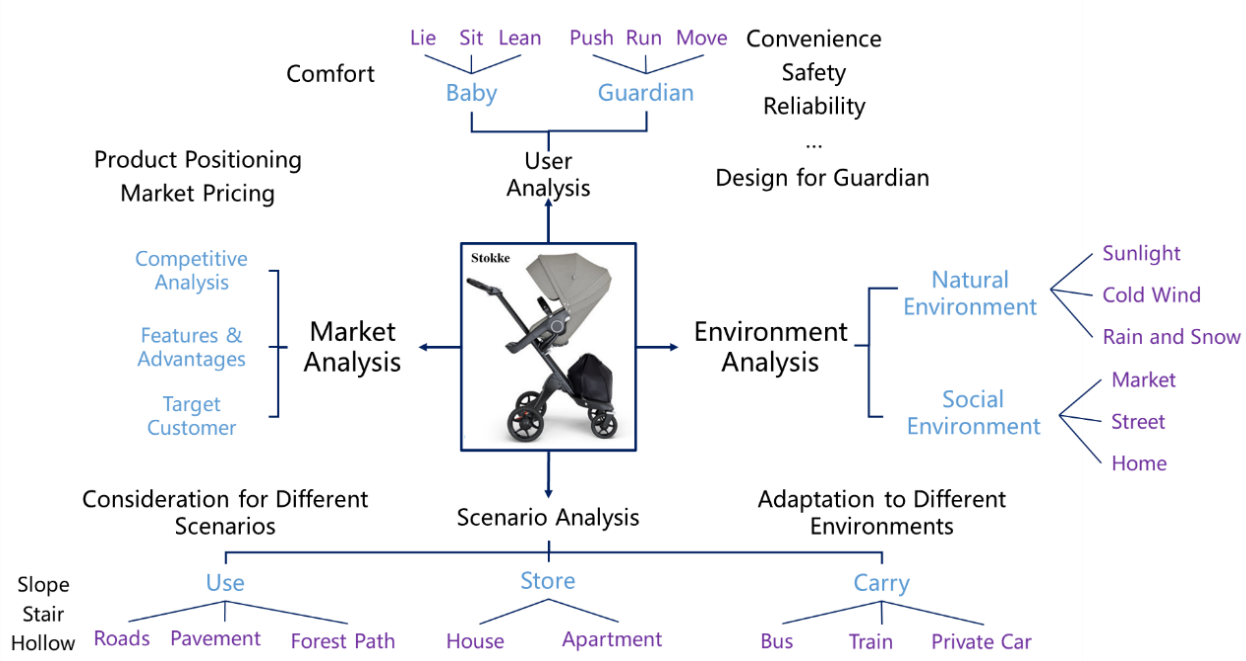

Figure 1. The requirement analysis of a stroller

4. Conclusion and outlook

This paper identified four kinds of design requirements, i.e. user, environment, scenario, and market. A step-by-step approach for systematic design requirements is proposed for design requirements analysis focusing on the four kinds of requirements sources. The design requirements analysis of the design of a new stroller is presented as a showcase of the proposed approach.

The future work is to continue working with further development of the proposed framework. Some data-driven design tools will be developed for assisting the design requirement analysis process.

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ESG 企業之品牌認同相關性研究

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摘要

生活型態在社會學中，生活型態（或生活風格、生活方式）是一個人（或團體）生活的方式。集合文化、社交、娛樂甚至是消費行為，通常反映一個人的態度、價值觀或世界觀，這些特徵行為顯現出生活上的差異，在團體及社會中尤其明顯，以市場行銷的角度來看，消費者的購買行為顯然與特定生活型態相輔相成，可說是不斷整合後所產生出的結果，我們可以順利地從不同世代的生活型態中掌握形象特徵。在提到市場行銷便不得不重視消費者，一個品牌的成功關鍵必將經由多數的消費者認同並提攜。保留顧客，降低顧客流失率為各企業的首當任務，多數消費者將選擇最能滿足心理期待的商品。因此「品牌認同」在如今競爭激烈的市場機制下顯得格外重要。

ESG（Environment、Social Responsibility、Corporate Gobernace），為環境保護、社會責任、公司治理，做為新的市場概念備受關注。我們將探討消費者行為對 ESG 品牌認同的作用，及 ESG 本身對消費者及社會的影響。而企業中的消費者，不同的集群的在媒體接觸行為有部分差異，我們使用問卷調查法，收集各種年齡層中不同性別、工作狀況、教育程度、婚姻的人的生活型態將其進行樣本分析，以知曉生活型態對於品牌認同的高低。

為使不認同企業品牌的族群融入其中，各大企業都須做足充分的準備，希望時尚、樸素群能夠擁有美好的生活型態。我們得到的結果為性別上對於 ESG 品牌認同度女生高於男生、年齡上對於 ESG 品牌認同度較無明顯差別、教育程度上對於 ESG 品牌認同度較無明顯差別、婚姻上對於 ESG 品牌認同度較無明顯差別、工作狀況上對於 ESG 品牌認同度較無明顯差別、生活型態上對於 ESG 品牌認同度時尚群高於樸素群，由此可見，時尚群對自己的生活會有較高的期許和變化，勇於嘗試新的事物追求流行跟上時代腳步，相對的樸素群較為保守且較無新意。

關鍵字：ESG、品牌認同、生活型態

第一章 緒論

1-1 研究動機

近期新的市場概念 ESG（Environment、Social Responsibility、Corporate Gobernace）環境保護（Environment）、社會責任（Social Responsibility）、公司治理（Corporate Gobernace），原本 ESG 只有提到上面三個面向，但 ESG 也代表一種企業社會責任，可用來衡量一間企業的社會責任表現，並利用這個分數衡量企業的外部風險，借以評斷未來績效，如果公司為了讓財報好看而對這些數據作假，這樣就難以獲得市場認可 ，以致於部分投資人會利用 ESG 分數來選股，作為股票獲利的指標。

1-2 研究目的

本研究的目的在於探討消費者對於 ESG 品牌的認同如何受到消費者生活型態的影響。本研究採用問卷調查受訪者的性別、年齡、學歷、工作，以及活動、興趣、意見等生活型態問題

1-3 研究範圍

本研究透過在社群網路上發放問卷的方式蒐集資料，調查統計台灣有使用網際網路的消費者，研究消費者生活型態是否會影響對於 ESG 企業品牌認同的看法，其他關於品牌的變數不在研究範圍

第二章 文獻探討

2-1 生活型態和品牌認同之關聯

生活型態是受到外界影響，如文化價值、參考群體或家庭、規範性順從與資訊的影響。生活型態是說明你個人特定的生活模式，而品牌認同(brand identity)是指品牌管理人想要人們如何看待此品牌。並通過以下兩個研究，王俊仁、張家揚（2008 年），林香如、蕭如妙（2011 年），確定生活型態會對品牌認同有所影研究方法

第三章 研究方法

通過設計 ESG 企業的經營理念和品牌認同相關的問題並做篩選，將品牌認同篩選出八題，消費者生活型態則是篩選出十九題並分為七類，基本資料五題並經由吳明隆（2021）網路問卷調查蒐集資料，並針對遺漏值進行處理若參與者在單一量表中若遺漏題數超過 50%，則該量表則視同完全遺漏。參與者若在單一量表中遺漏題數低於 50%，則遺漏項將會由其他有作答的題目總分平均數進行填補。永析統計諮詢顧問（2017 年）黃國光（2000）吳明隆（2013）而後使用群集分析法 k-組平均法先決定分群的目標數為兩組，並比較各觀察值與群集中心點的距離，與中心點距最接近的觀察值將會被歸屬於同群集之中。最後進行描述性

統計與組間比較以及事後比較連續變項使用永析統計諮詢顧問（2017 年）獨立樣本 t 檢定、ANOVA 與 Scheffé 事後檢定。本研究統計上的顯著水準統一訂為 p<0.05

第四章 研究分析

根據問卷調查取得之基本資料將性別、年齡、婚姻狀況、教育程度、工作狀況、消費者生活型態、品牌認同進行敘述性統計分析敘述性統計分析。

將基本資料分為性別、年齡、教育程度、婚姻狀況、工作狀況等指標。

表 1 樣本敘述性統計摘要表

變項		人數	百分比
性別	男性	60	24.0
	女性	190	76.0
年齡	13-19 歲	52	20.8
	20-29 歲	147	58.8
	30-39 歲	24	9.6
	40-49 歲	13	5.2
	50-61 歲	14	5.6
婚姻狀況	已婚有小孩	28	11.2
	已婚無小孩	4	1.6
	未婚	214	85.6
	離婚	4	1.6
教育程度	高中職(含)以下	80	32.0
	專科	14	5.6
	大學	132	52.8
	研究所(含)以上	24	9.6
工作狀況	全職工作者	73	29.2
	全職學生	118	47.2
	自雇者	14	5.6
	待業	9	3.6
	退休者	1	0.4
	部分工時工作者	35	14.0

將消費者生活型態的問題分為 7 種不同的生活意識，並以 K-組平均法將其分為兩個族群，並由集群中心分數的對照，可以得出到兩組間時尚新潮意識的差異最大，於是將分數高的稱為時尚群，為樸素群。而後進行分析統計

表 2 生活意識敘述性統計摘要表(總額)

	最小值	最大值	平均值	標準偏差
C1 新生活意識	1.00	5.00	3.6336	0.78153
C2 廣告意識	1.00	5.00	3.1850	0.86633
C3 時尚新潮意識	1.00	5.00	3.0080	0.95368
C4 飲食健康意識	1.00	5.00	3.4189	0.78056
C5 個性成就意識	1.00	5.00	3.6620	0.86123
C6 隨意性意識	1.00	5.00	3.5340	0.99992
C7 家庭生活意識	1.00	5.00	3.7740	0.85019

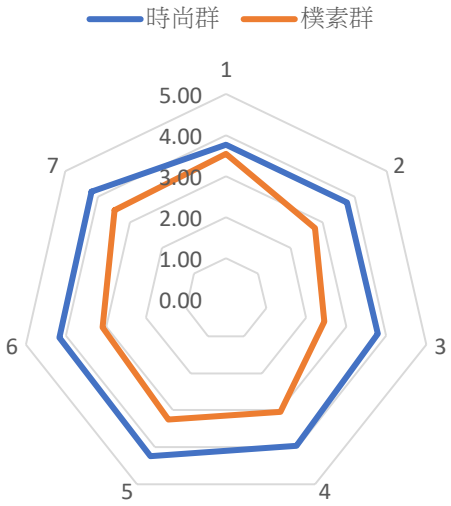

圖 1 集群分析雷達圖

1. 性別通過獨立樣本 t 檢定 顯示性別對 ESG 品牌認同有顯著影響。

2. 年齡經變異數分析顯示對 ESG 品牌認同無顯著影響。

3. 教育程度經單因數變異數分析顯示對 ESG 品牌認同無顯著影響。

4. 婚姻狀況經單因數變異數分析顯示對 ESG 品牌認同無顯著影響。

5. 工作狀況經單因數變異數分析顯示對 ESG 品牌認同無顯著影響。

6. 將生活型態時尚群，樸素群進行變異數分析顯示時尚群對 ESG 品牌認同度較高。

第五章　結論

5-1 結果與討論

綜合資料與分析，發現就 ESG 品牌認同度而言，女性相較於男性擁有更高的品牌歸屬感，同時個人在生活型態越是注重時尚感也增加其對品牌的追求，因此若是企業若是能針對此類客戶進行重點宣傳，對品牌提升所帶來的利益的效果會最大化，同時也能從中發現當主要客戶之族群越是靠近此兩類型態，就越需要注重企業之品牌形象，因其顯而易見的會影響客戶消費的意願

5-2 發現與建議

由於消費者對於社會越來越要求高品質生活，消費者思想也較沒有以前傳統，地球環保意識也逐漸提高正視，綜上所述在本研究的問卷題目上，我們想要以吳垠研究問卷為基礎，修改部份問項語詞以適用台灣社會，採用李克特五點量尺，計分方式為：1=完全不同意、2=不同意、3=無意見、4=同意、5=完全同意，在未來可能遇到由於我們是將問卷放在社群軟體上面，所以無法判別填寫問卷的性別為何，導致男女比例較不平均。還可能遇到認同企業品牌的族群，他們所追求的企業品牌已到達極致程度，需要讓較不認同企業品牌的族群循序漸進融入其中，所以各大企業須做好充足的功課來改變現況，望兩族群能夠擁有享受美好的生活型態。

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The application of Triz on improve cycling safety

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Abstract

Since promotion of leisure sports and environmental protection factors are valued. Bicycles are not only a transportation tool, but also one of the ways to exercise and save energy in transportation. Under the sharing economy, U-bike provides the convenience of transportation for many students and office workers, and also allows more people to ride bicycles. Although some cyclists install reflective devices on the rear of their bicycles and even install LED lights on their helmets to enhance safety, there are still many safety accidents caused by collisions.

In order to improve the safety of bicycles, this study attempts to find a better device by TRIZ method. Although there is no finished product after improvement, we still hope that it can be provided to the industry as a reference in the future.

Keywords: Triz, conflict matrix, cycling safety

1. Introduction

With the environmental protection factors and promotion of leisure sports, cycling is not only an energy saving tool of transportation, but also one of the ways to exercise. In Taiwan, Research Report of the Research and Development Evaluation Committee of the Executive Yuan, (2011) shows that government has promoted bicycle leisure activities in recent years. Since 1992, it has gradually constructed a local road network, connected the roundabout and regional road networks, and built a national leisure bicycle path system. In addition, government cooperates with enterprises to promote the sharing economy and set up U-bike bases in many locations to make bicycles more convenient for daily transportation. ()

In addition, cycling has many advantages, such as cycling may help you lost weight, strengthen cardiopulmonary function and promote blood circulation, increase muscular endurance, maintain good posture, Coordinate the nervous system, prevent brain aging, relieve stress, and so on. Therefore, in addition to daily life and transportation in Taiwan, many people go out to outskirts on holidays, the

number of cyclists has increased, and the number of bicycle accidents has also increased, especially in scenic spots. (Agarwal, A., 2021), (Oja, P., Titze, S.,etc., 2011)

When cyclists drive, they are often chased because there is no flash or reflective equipment behind them, especially in scenic spots at night. Although bicycles have pedal reflectors and rear reflectors, there are also a variety of clip-on LED lights on the market, such as headlights, tail lights, as well as LED helmets. Even with these devices, it can only be used as a reflection. When a cyclist wants to turn right or left, it cannot let the car behind knows. Thus causing the accident risk of a cyclist. (Y. Zeng, J. Liu , etc., 2004) From the 2016-2021 accident statistics from 7,777 to 11,905; the number of injured counts increased from 10,956 to 16,730; death toll counts from 89 to 147. (Ministry of Communications Statistics Inquiry Network, 111) ((Table 1)

Table 1. Number of incidents caused by cyclists from 2016-2021 in Taiwan.

	accidents	injured	death
2016	7,777	10,956	89
2017	8,106	11,444	94
2018	9,464	13,340	117
2019	10,684	15,064	133
2020	11,743	16,446	148
2021	11,905	16,730	147

In order to improve the safety of cyclist, we try to find better safety devices in the TRIZ way. First, we introduce TRIZ's problem-solving model, find the principles of improving cyclist safety from the TRIZ contradiction matrix, and try to find a solution. Then find possible solutions by ideal analogy. After that we make the final conclusion, hope though this research may improve cyclist safety.

2. Triz concept

TRIZ is the Russian acronym for the Theory of Inventive Problem Solving (Teoriya Resheniya Izobretatelskikh Zadach) which means the “theory of inventive problem solving” developed by Genrikh Altshuller and his school, beginning in 1946. It was virtually unknown in the West until a translation of one book by Altshuller was published in 1984 (Creativity as an Exact Science, by Gordon and Breach, New York). TRIZ theory is a systematic creative design method. Through this systematic method and a rule-based method, it can help solve various problems encountered in the process of innovation and can also find possibilities from the contradictions in the system. s solution. (Subzwari, K., Mokhov, S. .etc., 2006) (K. Rantanen and E. Domb, 2002)

In addition, TRIZ theory has the ability to innovate and solve abstract problems, and TRIZ theory can be applied in many different fields, for example, it can assist engineers to improve technical problems, find innovative solutions in the process of product development... etc., using a systematic

approach to find innovative solutions in an efficient way. Therefore, TRIZ theory is by far considered to be the most systematic way to solve problems and an important method of invention. (T.T. Chiu, T. K. Peng, etc, 2017)

To solve a technical problem, we first have to find the contradiction in the definition of the problem. Then we use the available resources to arrive at the Ideal Final Solution (or IFR) as closely as possible. This generally solves the problem at hand. Though this discussion is, to some extent, overly simplified one thing is clear; all problems must be stated in these terms in order to effectively utilize TRIZ.

The benefit of TRIZ is understanding that contradictions can be methodically solved with application of innovative solutions. Three fundamental principles of TRIZ conceived as follows:

1. The ideal design is goal.
2. Contradictions help to solve the problems.
3. Innovation process can be configured as systematic.

TRIZ includes analytical tools that are necessary for problem solving and also it is knowledge-based tools that are necessary for system transformation and their theoretical foundations. Using all the information about the problems of the products, the analytical tools of TRIZ can be used for transforming, modelling and analyzing problems. Also, ARIZ is a special analytical tool that gathers substance-field analysis, conflict analysis, required function analysis and other techniques. TRIZ uses algorithmic approaches for improving legacy systems or designing new systems. Therefore, it includes to evaluate the available data rather than estimation. (Ismail Ekmekci, Mustafa Koksal, 2015)

The main goal of TRIZ method is to find the ideal solution or perfection. TRIZ methodology depends on four basic paradigms.

1. Contradictions
2. Perfection
3. Functionality
4. Using resources.

Altshuller also described TRIZ in the light of these paradigms by using a four-step process;

1. Describing the problems
2. Matching and comparing the general problem with TRIZ problems.
3. Finding TRIZ solutions
4. Developing the ideal solution for issues.

3. The 39-Engineering Parameters of TRIZ Methodology

Altshuller investigates classification, description problems from 2.8 million patents, divided into 39 engineering parameters for TRIZ Methodolgy. These parameters have been defined for moving and stationary objects...etc.. which escribed as follows:

Table 2. The 39-Engineering Parameters of TRIZ Methodology

The 39-Engineering Parameters of TRIZ Methodology	
1. Weight of moving object	21. Power supplied or consumed by object
2. Weight of stationary object	22. Energy loss by object
3. Length of moving object	23. Substance loss by object
4. Length of stationary object	24. Information loss
5. Area of moving object	25. Time loss
6. Area of stationary object	26. Quantity of matter
7. Volume of moving object	27. Reliability of object
8. Volume of stationary object	28. Accuracy of measurement
9. Rate of change, speed	29. Precision of production
10. Force exerted by object	30. Harmful influence of object's environment
11. Stress, pressure exerted upon object	31. Harmful effects caused by object
12. Shape of object	32. Ease of production
13. Stability of object's composition	33. Convenience of use
14. Strength of object	34. Ease of repair and maintenance
15. Durability of mobile object	35. Adaptability, versatility of object
16. Durability of stationary object	36. Complexity of object
17. Temperature of object	37. Difficulties in measuring, inspection
18. Illumination of object	38. Level of automation
19. Energy consumption by mobile object	39. Production rate
20. Energy consumption by stationary object	

4. The 40 Invention Principles

Altshuller also present 40-Invention Principles after placing 39-Engineering Parameters to find inventive solution for the problem after investigating actual patent solutions and these principles can be explained as follows:

Table 3. The 40 Invention Principle.

The 40 Invention Principle			
1. Segmentation	11. Beforehand cushioning	21. Skipping	31. Porous materials
2. Taking out	12.Equipotentiality	22. Blessing in disguise	32. Color changes
3. Local Quality	13. 'The other way around	23. Feedback	33. Homogeneity
4. Asymmetry	14. Spheroidality	24. Intermediary	34. Discarding and recovering
5. Merging	15. Dynamics	25. Self-service	35. Parameter changes
6. Universality	16. Partial or excessive actions	26. Copying	36. Phase transitions
7. 'Nested doll'	17. Another dimension	27. Cheap short-living	37. Thermal expansion
8. Anti-weight	18. Mechanical vibration	28. Mechanics substitution	38. Strong oxidants
9. Preliminary anti-action	19. Periodic action	29. Pneumatics and hydraulics	39. Inert atmosphere
10. Preliminary action	20. Continuity of useful action	30. Flexible shells and thin films	40. Composite material

5. Application of Triz conflict matrix method to find bicycle safety solution

▪5.1 Problem Defintion

Although the bicycle is equipped with a reflective device, on an unilluminated road, when the vehicle behind sees the reflective light, the distance is very close, and it is still easy to cause a collision. Therefore, some car owners install LED lights as a warning.

Bicycle LED lights can warn other vehicles and are more effective than reflective devices, but the headlights only warn the cars ahead, and the rear lights only warn the cars behind, and cannot indicate the direction of turning.

▪5.2 Problem solving in conflict Matrix

Based on the standard engineering parameter in TRIZ theory, the classical TRIZ contradiction matrix is queried, and shown in Table 4.

When “Improving Feature” is 28 (Measurement accuracy), “Worsening Feature” is 26(Quantity of substandce /the matter), the recommended inventive principles are obtained: 2 (Taking out), 3 (Local quality), 28 (Mechanics substitution). When “Improving Feature” is 28 (Measurement accuracy), “Worsening Feature” is 27(Reliability), the recommended inventive principles are obtained:

32 (Color changes), 3 (Local quality), 11 (Beforehand cushioning), 23 (Feedback). When "Improving Feature" is 28 (Measurement accuracy), "Worsening Feature" is 18 (Illumination intensity), the recommended inventive principles are obtained: 11 (Beforehand cushioning), 15 (Dynamics), 32 (Color changes).

Table 4. Problem solving in conflict Matrix

Improving Feature	Worsening Feature	
28 (Measurement accuracy)	26(Quantity of substandce /the matter)	2 (Taking out) **3 (Local quality)** 28 (Mechanics substitution)
	27(Reliability)	**32 (Color changes)** **3 (Local quality)** **11 (Beforehand cushioning)** 23 (Feedback)
	18 (Illumination intensity)	**11 (Beforehand cushioning)** 15 (Dynamics) **32 (Color changes)**

According to the above three groups of contradiction matrix solutions, it can be seen that 3 (Local quality), 11 (Beforehand cushioning), and 32(Color changes) are repeated parts, so we first understand the definitions of these three principles before analyzing

Principle 3. Local quality

A. Change an object's structure from uniform to non-uniform, change an external environment
B. Make each part of an object function in conditions most suitable for its operation.
C. Make each part of an object fulfill a different and useful function.

Conceived Solutions: Combine the bicycle seat cushion with the LED light

Principle 11. Beforehand cushioning

A. Prepare emergency means beforehand to compensate for the relatively low reliability of an object.

Conceived Solutions: A solution for the rear (front) to know the direction of the bicycle in advance. The bicycle seat cushion LED light is designed as a light with direction indication

Principle 32. Color changes

A. Change the color of an object or its external environment.
B. Change the transparency of an object or its external environment

Conceived Solutions: Designed in a more eye-catching color (such as red LED light) to make it more visible

Combining the solutions of the above three contradiction matrix ideas, the image of the solution is as shown in Figure 1.

Figure 1. Example of Cycling Safety Devices

6. Application of ideal analogy on bicycle safety

▪5.1 Ideal analogy

Idealism emphasizes that any technical system can continue to move towards the idealized realm, and the system can continue to become more reliable, simpler, and more effective through the ideal law. At TRIZ. In the idea, idealism through other ideas or concepts, hoped that it can be combined in order to achieve the desired function. The more idealized the system, the less cost it will cost, the simpler it is, and the more efficient it is.

According to idealism concept, we try to solve the problem by analogy. After select 'Embeds' and 'Solid' to query, obtained that: "One object can be embedded in another object". Since the car already has LED rearview mirror embedded products, we try to design the embedded LED in an analogous way. The car's rearview mirror and bicycle rearview mirror with LED lights, as shown in Figure 2. And Figure 3.

Figure 2. Car's LED rearview mirror

Figure 1. Example of ideal analogy on bicycle rearview mirror

7. Conclusions and Suggestions

There is a lot of literature proving that cycling has many health benefits in addition to being environmentally friendly. However, riding a bicycle is also more dangerous than driving or riding a motorcycle in a car accident. In the study, we used TRIZ's innovative method to find the solution as follows:

1. The seat cushion is embedded with a red LED turn signal.
2. Design the bicycle LED rearview mirror, and design the flashing way.

However, even if there is safety equipment, cyclists may not always install it. For the safety of cyclists, here are a few suggestions:

1. Designing bicycles with safety devices instead of safety features is an optional equipment.
2. Government regulations must require cyclists to wear helmets (as in Europe)
3. Extensive design of bicycle-specific environmental facilities (such as bicycle lanes)
4. Cyclists should also pay attention to their own safety, such as not rampaging, not running through when red lights on etc.

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Improving Customer Satisfaction for Green Packaging Using Kano Model

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Abstract

Sustainability is one of the most widely discussed issues in the packaging sector. With an excessive amount of waste polluting Indonesia every year and a poor waste management system, people are starting to consider the need of using environmentally friendly products and the importance of reducing waste. This paper proposed Kano model of customer satisfaction for green packaging to demonstrate how it can be used to make customer perception of green packaging distinct. This study is aimed to identify which quality characteristic in green packaging that satisfy the most for customer. In addition, this research also want to recognize if the consumers are willing to pay more if they already meet their expectation regarding green packaging. This study composed a list of eight categories over 21 quality attributes of green packaging, to see which ones have the greatest impact on customer satisfaction. According to the findings, the most prevalent quality attribute used to identify the features was attractive, followed by must-be, reverse, one-dimensional, and indifferent. The importance strength score was proposed by this study that can reinforce the evaluation for designing or manufacturing green packaging. As a result, companies or designers will be able to recognize how to improve customer satisfaction and encourage environmentally friendly product and packaging strategies.

Keywords: customer satisfaction, green packaging, Kano model.

1. Introduction

Over the past decades, environmental issues are becoming more complex along with rapid economic growth. Currently, people are becoming more aware of environmental protection and starting to make an effort to help mother earth become a better place to live. One of the ways is changing towards a more green and sustainable lifestyle. Green packaging has emerged in the world to help mitigate the environmental challenge. As a developing country, Indonesia is one of the countries that fight against environmental problems. While green packaging was introduced decades

ago, it has only begun to emerge in Indonesia, since not many Indonesian people are aware of environmental problems until recent years.

Significant attention has been paid in the recent past to make product packaging more safe, eco-friendly, recyclable, and reduce carbon footprint as well (Bone and Corey 2000; Cleveland et al. 2005; Rokka and Uusitalo 2008). The consciousness of companies about the environment is rising in Indonesia itself, as can be seen from the growing number of initiatives by companies that indicate how they concern more about the environment (Alamsyah and Syarifuddin, 2018). When more and more eco-friendly products emerge, businesses are competing to develop different strategies to encourage buyers to purchase products that are eco-friendly (Alamsyah et al., 2017).

2. Motivation

Packaging is one of the factors that create pollution to the world and therefore become an issue that needs attention. Most consumers only want a product that suits their needs but does not think about how it impacts the environment. Furthermore, the growth of customers' attention toward the environmentally friendly is slow due to the high cost of the product. Businesses have higher difficulties to maintain the interest and gain the attention of customers. In practice, green appeals are not likely to attract mainstream consumers unless it fulfills their satisfaction. Moreover, limited research relating to green packaging using the Kano model has been conducted, especially in Indonesia. Therefore, it's a great opportunity to investigate further in this field.

3. Objective

The objective of this study is to identify quality attributes in green packaging that bring the most satisfaction for the customer using Kano model. Thus it will create a competitive advantage for companies as well as yield environmental benefits. This research also wants to recognize if the consumers are willing to pay more if they already meet their expectations regarding green packaging. Moreover, this study is to offer preferable suggestions by studying customer satisfaction for green packaging using the Kano model.

4. Literature Review

4.1 The Importance of Packaging

As it is the first level of contact between a product and customers, packaging is of great importance. In addition, packaging may be showing characteristic of a product, as well as the company's principles towards environmentally friendly packaging strategies, sustainability, and environmental preservation. Packaging can be an important tool in shaping customer behavior in terms of recycling and, consequently, in the evaluation of the product supply chain's packaging life cycle (Dellis, 2017).

4.2 Packaging Functions

Packaging has many functions and different categorizations for these functions have been suggested in previous research (Prendergast and Pitt, 1996; Rundh, 2005). Three key fundamental categories that occur in the literature related to the function of packaging are containment and handling, protection and preservation, as well as information and communication (Van Herpen et al., 2016).

4.3 Sustainable Packaging and the Development in Indonesia

Sustainable packaging, according to James et al. (2005), adds real value to society by effectively containing and protecting products throughout the supply chain, is designed to use materials and energy efficiently, is made up of continuously cycled materials, and does not poses health or environmental risks. Various organizations throughout the world have developed definitions of sustainable packaging such as the Sustainable Packaging Coalition and the Sustainable Packaging Alliance. Wal-Mart created a Packaging Scorecard to evaluate suppliers' packaging sustainability. A research by Wu and Tu (2018) concerning on evaluation indicator of green packaging design.

In Indonesia, the community started to direct themselves to use green packaging rather than regular packaging. Considering the growth of logistics, small-medium enterprises, and also food and beverage, green packaging business opportunities are very large (Rahadian et al., 2020). This suggests a considerable growth in consumer awareness of the importance of purchasing environmentally friendly items, as well as the domestic market's readiness to absorb products created in a sustainable manner.

4.4 Customer Satisfaction on Green Products

Customer satisfaction is a psychological term that includes the feeling of well-being and pleasure that comes from an attractive product or service that one hopes for and expects from (Pizam and Ellis, 1999). Customer satisfaction will increase profit because satisfied consumers would be willing to pay more for a product and more tolerant if there is a rise in price (Foedjiwati and Samuel, 2005). Wicks and Roethlein (2009) in their study about the definition of quality based on satisfaction mentioned that customer loyalty results in benefit, growth, and sustainability, regardless of the organizational type.

One study by Soegoto (2018) shows that the use of eco-friendly preferences can improve the quality of eco-friendly products, and the quality of eco-friendly products can improve customer satisfaction. Suki (2015) also claimed that product's environmental friendliness had a positive and significant impact on customer satisfaction with eco-friendly products. This suggests that businesses that incorporate green principles into their products might improve consumer satisfaction and loyalty while simultaneously meeting customers' environmental needs.

4.5 Kano Model

The Kano method was introduced in the 1984 to promote the design of innovative products in order to determine the coherence between market preferences, product attributes, and customer satisfaction, also to better understand the relationship between performance standards and customer satisfaction. A study by Jen and Bueso (2010) found that the Kano model challenged the traditional approach of customer satisfaction by differentiating performance on certain attributes to determine which one would yield the highest degree of satisfaction. This study also provides complimentary evaluations by using Fong's significance test and noise level reduction proposed by Berger to facilitate more detailed results.

5. Methodology

5.1 Kano Model

This study choose Kano model since it has been shown to be an effective tool for analyzing customer satisfaction characteristics (Kano et al., 1984). When achieved, the perceived quality categories affect the satisfaction of customers in distinct ways and are explained as follows:

1. **Must-be** or basic quality – This category of attributes is expected rather than required, and their fulfillment is not dependent on consumer satisfaction. Consumers are disappointed and would not be interested in the product if the product features in this category are missing or perform poorly.

2. **One-dimensional** or performance quality – customer satisfaction is a linear function of product attribute fulfillment, in other words, the higher the attribute output, the happier a customer becomes and vice versa. Generally, the customer especially demanded one-dimensional attributes.

3. **Attractive** or excitement quality – This category's attributes have the largest impact on customer satisfaction, since it increases super linearly as attribute achievement rises. However, the customer's satisfaction does not reduce as the attribute's fulfillment decreases—there are no unpleasant feelings. The customer does not directly convey or expect the attractive attribute.

4. **Indifferent** – the attributes that customers feel indifferent to. The satisfaction or lack of these attributes should not influence the satisfaction or dissatisfaction of customers.

5. **Reverse** – this attribute, when absent brings more satisfaction and when present brings dissatisfaction.

The starting point for the development of the Kano questionnaire is the product requirement which will be determined in an exploratory literature review. By doing so, we will obtain a general understanding of the basic criteria of green packaging. The exploration will then generate the parameter of product requirement. This study is planned to identify 21 quality attributes over eight categories. These attributes are described as shown in "Table 1".

Table 1. Quality Attributes of Green Packaging

Category	Quality Attribute	Description
Protection	Protective package	Effectively containing and preserving product in the supply chain.
	Protective structure	The design of packaging is considered protective.
Environmental Protection	Recyclable	Able to be recycled.
	Reusable	Able to be used more than once.
	Biodegradable	Material that can be degraded by bacteria or other natural sources of creatures without polluting the environment.
Communication	Informative	Contains information regarding the material content of the product.
	Eco-label	Recognizes products or services proven to be environmentally friendly within a certain category.
Material Resource	Mono-material packaging	Enhanced recycling time to be shorter and more efficient.
	Excessive packaging	Excessive boxes or layers in packaging.
	Reduce packaging	Optimizes the material strength to reduce the density of packaging.
	Bioplastic	Plastic derived from biomass
Pollution	Harmful material	Material that is damaging for environment such as toxic printing ink.
	Adhesive design	A substance that sticks two materials together, often can interfere the recycling process.
Convenience	Easy to carry	Packaging is able to be hold easily.
	Easy to storage	Packaging size is ideal to store.
	Easy to disintegrate	Easy to crush, tear apart, flattened (for recycling purpose).
	Easy to open	Allowing to utilize the content without difficulties to open.
	Resealable	Allowing to maintain the content's quality with reseal system.
	Lightweight	Replacing the packaging with lighter material in order to reduce weight.
Aesthetic	Aesthetically appealing	The packaging is aesthetically appealing while also committed to green packaging value.
Price	Increasing cost	The price of green packaging is increased.

The questionnaire is composed of two sections: the first one is aimed at profiling the participant in terms of gender, age, marital status, education, occupation, and income. The second one is a Kano quality two-dimensional questionnaire addressing the product quality elements. Online questionnaire platforms such as Google Form will be chosen to be the platform for delivering the questions for the respondents' easy review and reply.

The questionnaire used functional and dysfunctional questions method for each attribute. The customer chooses one of five alternative responses for each part of the questions: I like it that way; It must be that way; I do not care; I can live with it; I dislike it. The Kano questionnaire facilitates in the classification of customer satisfaction criteria into several categories of attributes and suggests how much consideration should be given to each product criterion in order to attain the desired level of customer satisfaction. By merging two responses from the customers' questionnaire, as demonstrated "Table 2", the nature of quality attributes can be determined. The response in the evaluation table to the functional and dysfunctional questions shows the nature of the quality attribute.

Table 2. Evaluation Table of Kano Model

Customer requirements		Dysfunctional				
		1. like	2. must-be	3. neutral	4. live with	5. dislike
Functional	1. like	Q	A	A	A	O
	2. must-be	R	I	I	I	M
	3. neutral	R	I	I	I	M
	4. live with	R	I	I	I	M
	5. dislike	R	R	R	R	Q

Customer requirements are:
A: Attractive O: One dimensional
M: Must-be Q: Questionable result
R: Reverse I: Indifferent

The next assignment will be carried out using the method of customer satisfaction coefficient (CS coefficient). A CS coefficient approach is able to assess whether meeting a quality requirement will increase the satisfaction of customers or whether it will merely avoid their dissatisfaction. Two coefficients will then be calculated in order to evaluate the average satisfaction impact.

The coefficient of increasing satisfaction formula will be:

$$= \frac{(A+O)}{(A+O+M+I)} \tag{1}$$

The coefficient of decreasing dissatisfaction formula will be:

$$= \frac{(O+M)}{(A+O+M+I)*(-1)} \tag{2}$$

The increase in satisfaction coefficient is in the range of 0~1, where closer to 1 means that the quality factor has a greater impact on increasing customer satisfaction; the customer dissatisfaction coefficient is in the range of-1~0, where closer to -1 implies that the function has a greater impact on decreasing customer satisfaction. A value closer to 0 means that unless performed, the attribute does not trigger dissatisfaction, as presented in “Figure 1”.

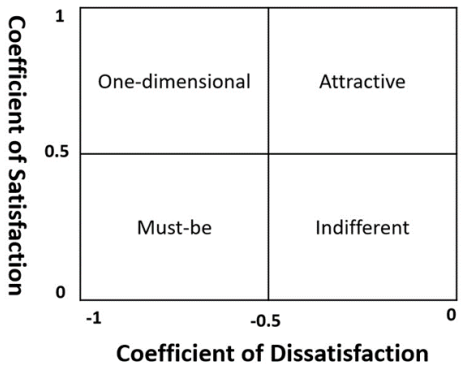

Figure 1. Customer Satisfaction Coefficient

3.2 Additional Evaluations

- Fong's Statistical Significance Test

Fong (1996) developed a statistical significance test that analyzes if there is a statistical significant difference between the two most frequent observations and quantifies the degree of difference between two closely ranked categories among the various quality attributes. Fong's equation is employed, in order to determine whether the attributes are significant. In Fong's equation, an attribute is considered important whenever the described expression is fulfilled:

$$|a + b| < Q \tag{3}$$

Q can be represented by:

$$Q = 1{,}65 * \sqrt{\frac{(a + b) * (2n - a - b)}{2n}} \tag{4}$$

a = the frequency of the most chosen attribute
b = the frequency of the second most chosen attribute
n = total number of responses

If expression (3) is true, then the attribute is considered as not significant. Else, then attribute is considered as significant. Furthermore, the attribute that is considered as non-significant by Fong's equation, is considered inconclusive.

- Noise Level Reduction Method

Noise level reduction method is another method to determine Kano category that proposed by the Center for Quality Management (Berger, 1993). The noise level reduction method creates a comparison method between positive and negative evaluation, where positive evaluation consists of attractive, one-dimensional and must-be attributes, on the other hand, negative evaluation consists of indifferent, reverse and questionable attributes. From the explained statement, it can be concluded that if the comparison falls into positive evaluation, the customer tends to expect the feature to be present in the product, while if the comparison falls in negative evaluation, the customer tends to disregard the feature to be present in the product. Therefore, the value needs to be evaluated to decide which one has higher value. After the highest value is found, the attribute of the feature will be identified by the highest frequency to specify in which category the feature stands. This method can be used to reconsider the inconclusive result according to Fong's equation. The noise level reduction method also can be expressed by this algorithm:

If, (A + O + M) > (I + R + Q),
Then, take the highest value from one-dimensional, attractive, or must-be,
Else, take the highest value from indifferent, reverse, or questionable.

- Importance Strength Score

Importance strength score is carried out by asking the respondent the three most important attributes, then each chosen attribute is given points 10, 5, and 2.5. The summary of each attribute is calculated and the total score from all of the attributes is identified, then scaled to the maximum score of 100. Therefore, the summary of each attribute is scaled down appropriately to the scale of 100. In this way, it will yield the following expression:

$$P_{si} = \frac{P_i \sum Ps}{\sum P} \tag{5}$$

Pi = importance point of i attribute,
Psi = scaled importance point of i attribute
$\sum p$ = total of attribute importance point
$\sum ps$ = total of scaled attribute importance point
i = 1, 2, 3, …, is the number of referred attribute

6. Analysis

There is a total of 307 correspondents who have filled the questionnaire. Twenty one of quality attributes over eight categories showed in the questionnaire are determined on data collecting process. The respondents consist of by 66% male and 34% female. The age group of 21 – 30 years old had the largest proportion of respondents. The respondents reported a wide range of occupations, the highest frequencies were full-time employees for 37%.

Individual respondent's assessment results of quality attributes for each feature are then accumulated that will generate the result as shown in "Table 3". There were 11 attributes obtained from attractive, which is the most preferred quality in this study. Based on the customer satisfaction coefficient, "Easy to Storage" has the highest satisfaction, followed by "Eco-label" and "Reduce Packaging". There were two attributes identified as one-dimensional, which are "Easy to Carry" and "Lightweight". In addition, the attributes that has the highest extent of dissatisfaction in must-be are "Easy to Open", "Informative", and "Protective Structure". The Kano model analysis result showed that "Increasing Cost" is categorized as indifferent. This study also found several attributes that are classified as reverse such as "Excessive Packaging", "Harmful Material" and "Adhesive Design". The next step would be to transfer the aforementioned result into a graphical form of the Kano model based on the coefficients of satisfaction and dissatisfaction, as displayed in "Figure 2".

Table 3. An Overview of Quality Attributes and CS Coefficient

Category	Quality Attribute	A	O	M	I	R	Q	Total	CS	DS	Kano Classification
Protection	Protective package	48	76	115	60	4	4	307	0.41	-0.63	M
	Protective structure	58	83	103	57	4	2	307	0.46	-0.61	M
Environmental Protection	Recyclable	145	60	41	53	4	4	307	0.68	-0.33	A
	Reusable	153	53	24	70	2	5	307	0.68	-0.25	A
	Biodegradable	126	71	50	58	2	0	307	0.64	-0.39	A
Communication	Informative	52	72	123	55	4	1	307	0.41	-0.64	M
	Eco-label	122	91	41	49	2	2	307	0.70	-0.43	A
Material Resouce	Mono-material packaging	151	39	24	87	2	4	307	0.63	-0.20	A
	Excessive packaging	9	8	8	117	161	4	307	0.11	-0.11	R
	Reduce packaging	147	62	14	74	9	1	307	0.70	-0.25	A
	Bioplastic	151	45	37	64	7	3	307	0.65	-0.27	A
Pollution	Harmful material	6	2	0	34	264	1	307	0.19	-0.04	R
	Adhesive design	10	6	2	91	196	2	307	0.14	-0.07	R
Convenience	Easy to carry	87	124	37	57	2	0	307	0.69	-0.52	O
	Easy to storage	137	96	26	44	3	1	307	0.76	-0.40	A
	Easy to disintegrate	150	52	37	64	1	3	307	0.66	-0.29	A
	Easy to open	45	96	105	52	5	4	307	0.47	-0.67	M
	Resealable	132	74	31	68	0	2	307	0.67	-0.34	A
	Lightweight	97	111	44	54	1	0	307	0.67	-0.50	O
Aesthetic	Aesthetically appealing	167	40	17	81	2	0	307	0.67	-0.18	A
Price	Increasing cost	25	8	6	157	106	5	307	0.16	-0.07	I

Note: A: Attractive, O: One-dimensional, M: Must-be, I: Indifferent, R: Reverse, Q: Questionable, CS: Customer satisfaction coefficient, DS: Customer dissatisfaction coefficient.

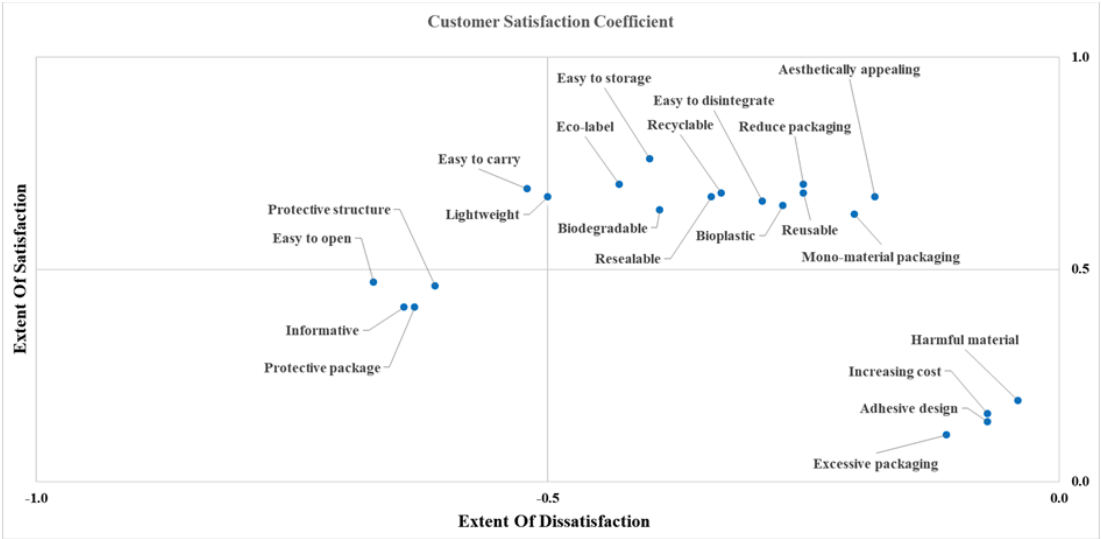

Figure 2. Graphical Form of Kano Model

In order to obtain advanced result from Kano model classification that were displayed above, additional evaluation analysis is applied. Fong's statistical significance test (Fong, 1996) and Berger's

noise level reduction methodology (Berger, 1993) offered another approach to reconsider the inconclusive result based on Fong's statistical significance test.

The findings of Fong's statistical significance test are presented in "Table 4". "Easy to open" and "Lightweight" are two of the 21 quality attributes that are statistically insignificant, which means they are regarded inconclusive. In addition, "Table 5" shows the result of using the noise level reduction methods. The outcome for "Easy to Open" showed that the sum of (A+O+M) is larger than (I+R+Q), therefore this attribute categorized as must-be. For "Lightweight", the total of (A+O+M) is larger than the total of (I+R+Q), thus this attribute is identified as one-dimensional. The value of the most frequent response for positive and negative evaluation attributes can be seen on "Table 3".

"Table 6" presented a list of those quality attributes that are considered inconclusive. It is determined that "Easy to Open" and "Lightweight" quality attributes are belong to must-be and one-dimensional quality respectively. The same result are shown from both Kano analysis approach and the noise level reduction approach.

Table 4. Fong's Statistical Significance Result

Category	Quality Attribute	Most frequent response	Second most frequent response	|a-b|		Q	Result	Kano Results Statistical Significance
Protection	Protective package	M	O	39	<	18.93	Not true	Significant
		115	76					
	Protective structure	M	O	20	<	18.79	Not true	Significant
		103	83					
Envronmental protection	Recyclable	A	O	85	<	19.28	Not true	Significant
		145	60					
	Reusable	A	I	83	<	19.66	Not true	Significant
		153	70					
	Biodegradable	A	O	55	<	19.09	Not true	Significant
		126	71					
Communication	Informative	M	O	51	<	19.03	Not true	Significant
		123	72					
	Eco-label	A	O	31	<	19.46	Not true	Significant
		122	91					
Material resource	Mono-material packaging	A	I	64	<	19.92	Not true	Significant
		151	87					
	Excessive packaging	R	I	44	<	20.35	Not true	Significant
		161	117					
	Reduce packaging	A	I	73	<	19.62	Not true	Significant
		147	74					
	Bioplastic	A	I	87	<	19.50	Not true	Significant
		151	64					
Pollution	Harmful material	R	I	230	<	20.43	Not true	Significant
		264	34					
	Adhesive design	R	I	105	<	20.40	Not true	Significant
		196	91					
Convenience	Easy to carry	O	A	37	<	19.42	Not true	Significant
		124	87					
	Easy to storage	A	O	41	<	19.84	Not true	Significant
		137	96					
	Easy to disintegrate	A	I	86	<	19.48	Not true	Significant
		150	64					
	Easy to open	M	O	9	<	19.19	TRUE	Not Significant
		105	96					
	Resealable	A	O	58	<	19.30	Not true	Significant
		132	74					
	Lightweight	O	A	14	<	19.35	TRUE	Not Significant
		111	97					
Aesthetic	Aesthetically appealing	A	I	86	<	20.06	Not true	Significant
		167	81					
Price	Increasing cost	I	R	51	<	20.23	Not true	Significant
		157	106					

Table 5. Noise Level Reduction Result

Category	Quality Attribute	Most Frequent Response of Positive Evaluation	Most Frequent Response of Negative Evaluation	O+A+M		I+R+Q	Final Category
Protection	Protective package	M	I	239	>	68	M
	Protective structure	M	I	244	>	63	M
Environmental protection	Recyclable	A	I	246	>	61	A
	Reusable	A	I	230	>	77	A
	Biodegradable	A	I	247	>	60	A
Communication	Informative	M	I	247	>	60	M
	Eco-label	A	I	254	>	53	A
Material resource	Mono-material packaging	A	I	214	>	93	A
	Excessive packaging	A	R	25	<	282	R
	Reduce packaging	A	I	223	>	84	A
	Bioplastic	A	I	233	>	74	A
Pollution	Harmful material	A	R	8	<	299	R
	Adhesive design	A	R	18	<	289	R
Convenience	Easy to carry	O	I	248	>	59	O
	Easy to storage	A	I	259	>	48	A
	Easy to disintegrate	A	I	239	>	68	A
	Easy to open	M	I	246	>	61	M
	Resealable	A	I	237	>	70	A
	Lightweight	O	I	252	>	55	O
Aesthetic	Aesthetically appealing	A	I	224	>	83	A
Price	Increasing cost	A	I	39	<	268	I

Table 6. Inconclusive Quality Attribute Result

Inconclusive Quality Attribute	Original Kano Classification	Noise Level Reduction Method	Final Classification
Easy to open	M	M	M
Lightweight	O	O	O

As the last part of the questionnaire, respondents were asked to choose the three most important attributes that they think should be included in green packaging. Final score of 21 quality attributes were calculated by summating all the responses, as shown in “Table 7”. Every most important, second most important, and third most important are given score 10, 5, and 2.5 respectively. Then it will be scaled in 100 score range to determine which item is the most important item according to the customer's preferences.

From “Table 7”, it can be concluded that “Recyclable”, “Protective Package”, and “Biodegradable” are considered as the three most important attributes that customers hope to be present in green packaging. On the contrary, “Lightweight” , “Resealable”, and “Easy to open” are the three least important attributes in green packaging according to respondents. This table does not consider the division between basic requirements, performance requirement or excitement requirement as must be, one dimensional, and attractive in Kano model. However, this table represents the most expected quality attribute that customer hope will be present in the desired product without considering Kano classification.

Table 7. Importance Strength Score Result

Category	Quality Attribute	The Most Important	The Second Most Important	The Third Most Important	Final Score
Protection	Protective package	82	35	21	19.50
	Protective structure	5	10	8	2.23
Environmental Protection	Recyclacle	64	69	29	19.68
	Reusable	35	39	26	11.35
	Biodegradable	58	46	53	17.54
Communication	Informative	10	24	19	4.98
	Eco-label	5	11	16	2.70
Material Resource	Mono-material packaging	3	3	6	1.12
	Non-excessive packaging	0	2	5	0.42
	Reduce packaging	4	2	11	1.44
	Bioplastic	3	12	6	1.95
Pollution	Non-harmful material	18	26	42	7.72
	Non-adhesive design	1	3	4	0.65
Convenience	Easy to carry	2	8	20	2.05
	Easy to storage	1	5	2	0.74
	Easy to disintegrate	9	6	18	3.07
	Easy to open	0	0	0	0.00
	Resealable	1	0	0	0.19
	Lightweight	0	1	3	0.23
Aesthetic	Aesthetically appealing	3	2	11	1.26
Price	Cost not increase	3	3	7	1.16
Total		307	307	307	100

7. Conclusions

Packaging creates a good first impression in the store. It also has an effect on the customer's perception of the product's quality after they have purchased it. Increasing environmental consciousness of consumers has given a chance to companies or designer to understand the demand of their consumers. This research proposed Kano's model of customer satisfaction for green packaging in order to demonstrate how it can be used to make customer perception of green packaging distinct. This demonstrates the importance of customer satisfaction and enables designers or companies to conduct similar evaluations, thus enhancing users' overall satisfaction.

The Kano model classification can be evaluated by categorizing the quality attributes that the potential consumer has been addressed into three categories: attractive, one-dimensional, and must-be. Nonetheless, the specification of the products are better understood. Exploring and implementing attractive quality attributes could open up to a world full of differentiation possibilities. A product that just meets the must-be and one-dimensional needs are regarded as ordinary and thus indistinguishable (Matzler and Hinterhuber, 1998).

This study integrate additional evaluations from Fong's statistical significance approach to find whether the attribute are statistically significant. Every attribute that does not categorized as significant are specified as inconclusive which will be compared with Berger's noise level reduction approach. Furthermore, the classification from Kano model method and noise level reduction approach derives the same result which means despite of its insignificance level, those attributes can still be classified accordingly to Kano model classification. This study also proposed an importance strength score that

can reinforce the evaluation for designing or manufacturing green packaging without considering Kano model classification.

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ECT 与意见领袖探讨影响大学生红色旅游计划重要因素调查

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摘　要：

本文首先从红色旅游发展的背景入手，基于 ECT 模型、意见领袖模型以及前人所探讨的影响旅游的持续使用意愿的因素，整理出信任、知名度、专业度、满意度、关系强度、期望确认、感知有用性以及持续使用意愿这六大变量，从而构建本文的研究模型。然后通过问卷调查法收集数据，利用 SPSS 统计软件分析量表的信度和效度，并采用结构方程模型的分析软件 Amos 检验研究模型的假设，研究发现，知名度对信任产生正向影响，专业度对信任产生正向影响，关系强度对信任产生正向影响，期望确认、感知有用性对行为意愿有正向影响。最后，提出旅游业要提高意见领袖的知名度、专业度、关系强度，提高旅游者对意见领袖的信任三方面建议。

关键词：ECT；意见领袖；红色旅游；影响因素

Abstract:

This paper firstly starts from the background of red tourism development, based on the ECT model, the opinion leader model and the factors affecting the continued use of tourism as discussed by previous authors, the six variables of trust, popularity, professionalism, satisfaction, relationship strength, expectation confirmation, perceived usefulness and continued use intention are collated to construct the research model of this paper. The data was then collected by questionnaire method, the reliability and validity of the scale were analysed using SPSS statistical software, and the hypotheses of the research model were tested using Amos, the analysis software for structural equation modelling. The study found that awareness had a positive effect on trust, professionalism had a positive effect on trust, relationship strength had a positive effect on trust, and expectation confirmation and perceived usefulness had a positive effect on willingness to act. Finally, three suggestions are made for the tourism industry to improve the awareness, professionalism and relationship strength of opinion leaders and to increase the trust of tourists in opinion leaders.

Keywords: ECT; opinion leaders; red tourism; influencing factors

一、 引言

（一）研究背景

全国旅游占比我国 GDP 比重为 4.05%。文旅部数据显示：根据国内旅游抽样调查统计结果，2022 年上半年，国内旅游总人次 14.55 亿，比上年下降 22.2%。其中，城镇居民国内旅游人次 10.91 亿，下降 16.6%；农村居民国内旅游人次 3.64 亿，下降 35.4%。分季度看，其中一季度国内旅游人次 8.30 亿，同比下降 19.0%；二季度国内旅游人次 6.25 亿，同比下降 26.2%。国内旅游收入（旅游总消费）1.17 万亿元，比上年下降 28.2%。其中，城镇居民旅游消费 0.94 万亿元，下降 26.7%；农村居民旅游消费 0.23 万亿元，下降 33.8%[1]。因为疫情原因导致全球旅游人次下降，预计后续旅游人数会持续上涨。

预测 2025 年全国旅游及相关产业增加值占 GDP 比重为 5%。旅游的规模已经这么大了，我们应该科学研究旅游，使得我国更加繁荣昌盛。

（二）研究目的

根据上述研究背景，本研究的目的在于希望整合型期望确认模型（ECT 模型）、持续使用意愿模型，并加入意见领袖，了解红色旅游者的持续使用意愿。主要研究目的为：第一，以整合期望确认模型（ECT 模型）、持续使用意愿模型，探究意见领袖对红色旅游的持续使用意愿；第二，加入意见领袖因素，探究意见领袖对红色旅游者的持续使用意愿的影响；第三，基于最新问卷法采集数据以多维度探究使用者的持续使用意愿，希望对红色旅游企业的发展有所帮助。

二、文献综述

本研究针对 ECT、意见领袖和红色旅游做相关文献探讨如下：

（一）ECT 的研究

（1）ECT 的概念

ECT（Expectation confirmation theory）又叫做期望确认理论，是由 Oliver(1980)提出的，研究消费者满意度研究的基本理论，主要的概念为消费者是以购前期望(Expectation)与购后绩效(Perceived Performance)表现的比较结果(Confirmation)，判断是否对产品或服务满意(Satisfaction)，而满意度则成为下次再度购买或使用(Repurchase Intention)的参考[2]。Oliver 于 1980 年提出，用来研究用户的满意度和持续使用行为中，2001 年被 Bhattacherjee 拓展和完善，

形成了期望确认模型。模型中加入了感知有用性，且感知有用性直接影响用户的满意度和持续使用意愿[3]。该理论认为用户在使用产品或服务之前会对产品或服务产生期望，当使用之后，会根据自己对产品和服务的使用及认知与之前的期望进行比较,产生了期望确认，期望确认程度越高，用户感知有用性和满意度越高。

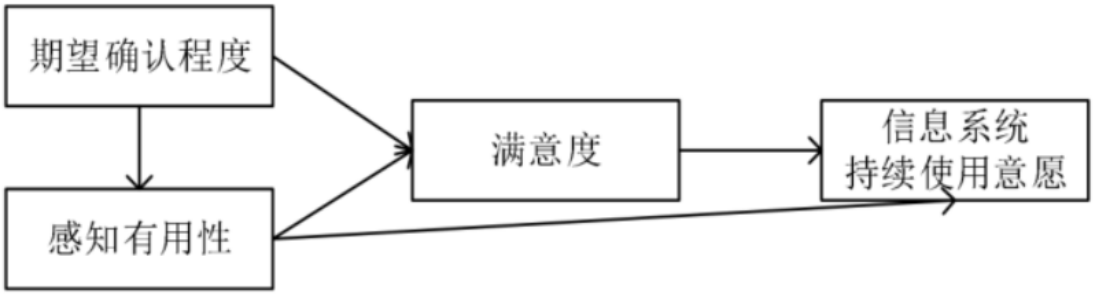
（2）国内外对 ECT 的研究

谢小玲（2021）提出 ECT 模型适用于共享电动汽车用户持续使用意愿的影响因素研究;期望确认度直接影响用户的持续使用意愿;期望的确认能促进用户感知声誉的形成,感知声誉通过影响感知有用性进而影响用户持续使用意愿[4]。

袁露（2019）研究发现,付费语言学习 APP 用户的期望确认度、感知有用性对满意度、持续使用意向有正向影响,感知信任、习惯对满意度、持续使用意向也存在正向影响[5]。

(Rahi 等人，2019）旨在开发一个综合模型，结合两个著名的理论期望确认理论（ECT）和自我决定理论（SDT）来确定客户对使用网络银行的持续意向[6]。IPMA 进一步证实，管理者需要更加关注系统质量、信息质量、用户满意度和 IT 技术能力。 (Gupta et. al.2020)通过增加感知健康结果和社会比较倾向来扩展期望确认模型，以了解智能健身变量的持续意向[7]。

综合相关文献发现我国学者用来研究共享电动汽车和 APP 的持续使用，西方学者用 ECT 来研究网络银行，很少有学者把 ECT 用来研究红色旅游景区的选择，本文创新将 ECT 和嘉兴南湖相结合，探讨两者的影响因素。



（图 1——信息系统持续使用意愿模型）

（二）意见领袖的研究

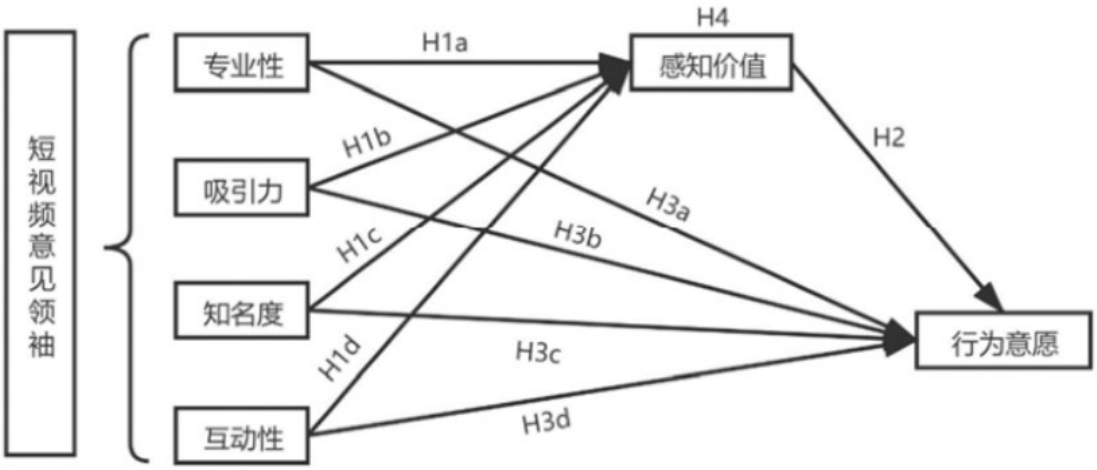
（1）意见领袖的概念

意见领袖(Key Opinion Leader，以下简称 KOL)作为新时代的一种标杆，能够影响到许多人对某种东西的看法。Stem&Gould 认为意见领袖影响他人的过程与口口相传很相似，也就是口碑的产生过程，通过有目的性的传播商家信息，增强人们对商品的可信度[8]。意见领袖在很多方面有所运用，西方学者，把他用在营养学、医学等领域。很少学者把意见领袖用在红色旅游，本文创新研究意见领袖与红色旅游相结合。本文以大学生为研究主体，研究意见领袖的影响力大小，知名度、专业度、关系强度、产品涉及是意见领袖的五个特性。

（2）国内外对意见领袖的研究

意见领袖这个概念最早源自于社会学家和传播学家 Lazarsfeld Berelson(1944)提出的两级传播理论[9]。意见领袖是两级传播中的重要角色，它并不一定是狭义上的真正“领袖”，他们并不是一定是管理者或者高层等，而是特指在某个领域具有一定的权威意见或影响力的人。除了在传播学上广泛运用后，Everett M. Rogers 将关键意见领袖引入市场营销领域，其认为意见领袖是可以不同程度的影响他人决策的人，意见领袖是在信息发布者中拥有一定的知名度，而其他人从意见领袖处可以获取意见和信息。本人认为关键意见领袖对产品的销售起到有效的宣传和推广作用[10]。（谢雪娇，2021）通过运用 S-O-R 理论、感知价值理论、行为意愿理论等构建了研究理论模型,以短视频意见领袖特征（包括专业性、吸引力、知名度和互动性）为自变量,以旅游者通过感知意见领袖发布的目的地短视频对目的地感知价值（包括认知和情感）为中介变量,来研究旅游者的目的地行为意愿,进一步探讨短视频意见领袖影响旅游者行为意愿的特点以及其影响程度[11]。（文彤等人，2022 年）在意见领袖的主体多元化、知识生产方式、信息传播方式、权力形成和保持方式等方面丰富了传统意见领袖和虚拟社区意见领袖的研究。此研究的局限在于不同旅游虚拟社区具有的不同平台环境和成员交往规则,会影响意见领袖网络权力的形成和表现特征,如去哪儿网是“旅游垂直搜索引擎”,“携程网”是主打“综合性旅行服务平台”,驴妈妈致力于打造“线上线下相结合旅游网站”。因此,旅游虚拟社区意见领袖网络权力的研究应考虑对不同旅游虚拟社区形成的网络结构和权力进行比较分析,通过更多的案例探究具有普适性的旅游虚拟社区网络权力特征和形成机制。[12]

综合以上相关文献发现西方学者把意见领袖用来研究公司意见领袖会影响员工的组织内行为，本研究创新把意见领袖拿来探讨消费者与意见领袖之间来选择红色旅游景区的影响因素。



（图 2——短视频意见领袖影响目的地行为意愿概念模型）

三、红色旅游的研究

发展红色旅游历来是党中央、国务院高度重视和高度重视的一个重要问题。《2016-2020年全国红色旅游发展规划纲要》明确提出，要大力发展“红色旅游”，就要加强爱国主义教育，加强革命传统教育，培育和践行社会主义核心价值观，推进社会主义精神文明建设，以“红色旅游”为重点，大力发展“红色旅游”[13]。十八大以来，习近平作为党中央的领导人，作出了一系列重要的决定，推动了红色旅游的持续、健康发展，实现了中华民族伟大复兴，弘扬了中华优秀传统文化。

国内学者（金婷，2020）指出嘉兴南湖红色旅游资源开发内容缺乏个性化差异、受众对象范围比较狭窄、推广路径单一、推广内容缺乏创意等问题，提出深入挖掘南湖红色旅游展现形式，丰富旅游产品包和建立并维护主流新媒体官方路径，做到大众全覆盖等建议[14]。

国内学者（王鹏飞和宋军同等人，2021）以“携程网”马蜂窝”猫途鹰”同程旅游"驴妈妈”五个旅游网站收集嘉兴南湖景区的 6846 条有效评论作为研究数据，研究红色旅游目的地的“认知—情感”三维模型形象感知,运用内容分析法与扎根理论对数据进行了分析处理，研究发现:首先,经过初级编码和概念化归类,嘉兴南湖景区的形象感知可以分为旅游景观、位置区划、文化底蕴、旅游设施与服务和旅游环境与氛围 5 个主类目。其次“认知—情感”三维模型在红色旅游目的地中的适用性得到验证。游客基于南湖的自然景观、基础设施与服务、红色文化氛围和对南湖的积极情感共同表达影响了对嘉兴南湖景区的总体形象感知,这也验证了“认知—情感”三维模型在红色旅游目的地中的可适用性。最后,在总体形象的感知方面“南湖红船”为核心节点[15]。

综合以上文献可以发现,以往对于红色旅游目的地和期望确认理论和意见领袖等方面的研究还未给予足够重视。本文创新将 ECT 和 KOL 两大理论相结合探讨影响大学生红色旅游计划重要因素调查。

三、模型构建及研究假设

（一）研究假设

3.1 知名度与信任

意见领袖的知名度会影响红色旅游消费者的信任：社会中的名人自身的吸引力会增强信息接收者对信息有效性的认可，产生直接而显著的影响。本文认为，因为意见领袖有较高的名气、专业性很强、被大众熟知，因此，他们的观点容易被人们知晓和被消费者相信和追随。梦非(2012)指出社会地位、公众熟悉度和名人效应这三者均能够用来表示意见领袖的知名度。意见领袖来源有公众领域内的名人，如明星、行业专家等，也有网络平台中大家熟知的人[16]。

本文认为意见领袖可以利用自己的知名度对当代大学生消费者进行有效的推荐和倡导，使消费者对红色旅游产生期望与意愿。并在后续投入大量时间精力进行调查研究。

基于此，本文提出假设

H1：意见领袖的知名度会对红色旅游消费者的信任产生显著影响。

3.2 专业度与信任

意见领袖的专业度会影响红色旅游消费者的信任：在信息传播过程中，传播者能力对传播效果发挥着不可忽视的作用，而衡量其个人能力的重要尺度之一是传播者的专业性。Weimann G.(1994)认为意见领袖因为专业技能的确定性减少了购买评估阶段的感知风险，具有较高专业能力的信息传播者的意见更容易被消费者青睐和采纳，专家发出的信息可以对购买决策产生至关重要的影响[17]。Rogers et al.(2003)表示，意见领袖要为大众提供指导,必须具备专业的知识，社区影响力和个人魅力，这些意见领袖能够从专业角度出发，使他人接受自己的观点，引发更多参与者的讨论，起到引导消费者决策的作用[18]。

Rotter(2010)指出意见领袖享有一定的知名度，具有专业知识，影响着消费者的行为[19]。朱茂然(2017)认为，意见领袖将自己领域内熟知的专业知识发布到社交媒体上，对网民的态度具有引导作用[20]。

本文认为，意见领袖因为熟悉产品特性，拥有丰富的专业知识，能够为他人提供产品信息进而影响他人的行为意图。

基于此，本文提出假设

H2：意见领袖的专业度会对红色旅游消费者的信任产生显著影响。

3.3 关系强度与信任

意见领袖的关系强度会影响红色旅游消费者的信任：消费者的购买意愿受到信息发送者与其关系强度的影响。Smith（2002）,研究发现，消费者的购买意愿收到信息发送者与其关系强度有关[21]。意见领袖位于社区的中心，积极主动参与到多个领域里，愿意与其追随者进行互动，为他人提供建议(Rogers et al.,2003)[22]。在网络中，有些意见领袖与粉丝之间保持着较高的粘性，他们会经常回答粉丝的问题，与粉丝进行讨论，在这种愉悦的网络互动中，消费者容易被意见领袖影响。

意见领袖与消费者拥有强关系时，更容易建立彼此间信任和产生购买意愿，从而直接影响购买决策。本文认为，意见领袖与消费者之间的关系强度会显著影响消费者的购买意愿和信任。

基于此，本文提出假设

H3：意见领袖的关系强度会对红色旅游消费者的信任产生显著影响。

3.4 产品涉及与信任

意见领袖的产品涉及会影响红色旅游消费者的信任：产品涉及分为两种，一种是情境性涉及，另一种是持续性涉及，前者是在特殊环境下的短时间涉及；后者是在长期使用过程中形成的个人经验。刘海群(2015)认为，对产品信息的不熟悉会促使消费者在决策时倾向于寻找行业内的专业人士或是对该产品有深入了解的人来获取产品的信息，这一行为影响着消费者是否购买产品[23]。

本文认为，当意见领袖对某个产品处于持续性涉及时，就越容易被消费者重视和信任，总之，一个乐于分享的高持续性产品涉及者往往也能成为该领域的意见领袖，并且意见领袖拥有极高的产品涉入度，由于极高的产品涉入度，红色旅游计划制定者更偏向于向意见领袖征求意见。

基于此，本文提出假设

H4：意见领袖的产品涉及会对红色旅游消费者的信任产生显著影响。

行为意愿：Fornell(1997)&Bhattacherjee(2001)认为行为意愿就是用户在较长一段时间内愿意继续使用该产品[24]。 从 20 世纪的 70 年代开始，企业从以产品为中心转向以客户为中心的企业，对消费者行为的研究成为各个行业关注的焦点。消费者行为意愿(Consumer Behavioral Intentions)是顾客对商品或服务的正面或负面的反应，从属于态度理论(Attitude Theory)。根据社会心理学，态度理论认为态度由认知(包括个体的知识与信念)、情感(包括个体的感知感觉情绪)以及意动(指个体的行为意愿)等构成[25]。而 Ajzen(1991)的研究认为行为意愿不是行为态度，行为意愿(Intention)是指行为产生的必要阶段同时它是消费者的心理、态度等受外部环境的刺激变化的表现。[26]因此，随着短视频病毒式算法的传播影响以及其意见领袖影响的扩大，短视频意见领袖推荐的目的地信息已成为旅游者目的地产品信息的重要窗口，对旅游者关于产品的认知、态度及意动都会产生相应的影响。本文认为，持续使用意愿就是我还会再来听取意见领袖的建议来参观红色旅游景点，其他任何方式不能替代意见领袖，我愿意长期使用，我还愿意向亲戚朋友推荐该意见领袖。

3.5 信任与持续使用意愿

信任会影响红色旅游消费者的持续使用意愿：Mayer（1995）认为信任是指“信息接收者对信息发布者所发布信息无条件的接受的心态，并且有能力承担信息不真实的风险[27]。”本文认为信任是指消费者对意见领袖的无条件接受的信赖，并且有能力承担信息不真实的风险，是一种相信倾向。

基于此，本文提出假设

H5：红色旅游消费者对意见领袖的信任会对红色旅游消费者的持续使用意愿产生正向影响。

3.6 期望确认与行为意愿

H6 期望确认：Oliver(1980)认为期望确认就是消费者在听取意见领袖前后产生的心理预估的对比，对使用前的期望确认度[28]。Bhattacherjee（2001）认为期望确认度就是消费者得到的服务比预期要高[29]。本文认为，期望确认就是消费者对意见领袖的期望在使用过程中得到了满足。

基于此，本文提出假设

H6：期望确认对红色旅游消费者的持续使用意愿产生正向影响。

3.7 感知有用性与行为意愿

H7 感知有用性:陈宣文（2018）关于“旅游 APP 用户持续使用意愿影响因素研究”论文中认为基于消费者心理层面，将感知价值归于消费者在交易过程中对产品或服务效用的综合评估，消费者会对将为此产品支付的成本和获取的收益进行综合性的对比和感知，所以顾客会优先购买他们认为感知价值最大的产品[30]。

基于此，本文提出假设

H7：本文认为感知有用性对红色旅游消费者的持续使用意愿产生正向影响。

3.8 满意度与行为意愿

H8 满意度：Oliver（1980）&Bhattacherjee（2001）认为满意度就是消费者是否满意的情绪以及该种情绪的高低程度。本人认为，满意度就是消费者听取意见领袖的建议用完产品后，感觉轻松愉悦，认为是个明智的决定。

基于此，本文提出假设

H8：本文认为满意度对红色旅游消费者的持续使用意愿产生正向影响。

3.9 知名度与行为意愿

知名度(Popularity)，根据百度百科，表示“一个组织或个人被公众知晓、了解的程度以及社会公众影响的广度和深度”。如 Rogers(2003)的研究表明，消费者青睐追随较高的社会地

位、公众熟悉度、知名度的人[31]。在如今的知识共享时代，意见领袖身份的形成具备多方面的途径，如 Bansal 等(2000)等指出博客作者在行业中的声望会影响其意见领袖口碑的效应[32]。意见领袖的知名度会带来消费者的信赖感。如 Macinnis 等(2002)的研究认为名人代言能带来崭新的品牌形象进而影响消费者[33]。Fang 等(2016)通过分析评论者中的意见领袖，发现其个人身份威望等因素会对旅游决策形成正向影响[34]。由于本文中意见领袖的影响对象是大学生红色旅游者的目的地行为意愿，因此意见领袖的知名度要针对红色旅游领域，本文选择了微博平台上旅游类博主为例，根据其粉丝量过百万为准。

基于此，本文提出假设

H9:意见领袖的知名度会对红色旅游消费者的行为意愿产生正向影响。

3.10 专业度与行为意愿

专业度(Professionalism) 一般指具备某个行业角色所必需的特定知识和技能的标准。专业性属于意见领袖的个人属性。Chan 等(1990)的研究表明意见领袖对产品越了解，其专业度越强，使其成为消费者咨询的对象可能性越大[35]。因此，在如今知识共享时代，专业性越强而且越频繁分享知识信息的人，越容易成为该领域的意见领袖。张潇满（2018）通过研究微信公众号的意见领袖为例，表明其专业性对用户的行为意愿有正向影响[36]。由于本文中意见领袖的影响对象是大学生的红色旅游者的目的地行为意愿，因此意见领袖的专业度要针对红色旅游目的地产品领域，其专业性应该不仅仅包括目的地的相关知识，还有传达目的地信息的表达能力。

基于此，本文提出假设

H10:意见领袖的专业度会对红色旅游消费者的行为意愿产生正向影响。

3.11 关系强度与行为意愿

关系强度也叫作吸引力(Relationship strength)，指使某事物或者某人看起来有趣、令人愉悦、值得拥有或去行动的特点或者品质。关系强度属于意见领袖的社会属性。Burns 等(1987）研究发现颜值带来的吸引力可以改变态度、强化信念，还有一定的引导作用[37]。Bower 等(2001）认为，具备强吸引力特征的人更容易使消费者产生可靠的感知[38]。短视频

意见领袖的吸引力维度主要是根据其外貌特征及内涵品质等方面来判断，一般来说。旅游者的感知价值与该意见领袖的吸引力成正比。除了外貌引发的吸引力外，研究者们还发现具有较高内涵修养的意见领袖发布的红色旅游信息可以为大学生红色旅游者带来较高的感知价值，使其感知到短视频意见领袖推荐的红色旅游目的地或旅游产品值得信赖，帮助自身更好地做出旅游决策。由于本文中意见领袖的影响对象是大学生红色旅游者的目的地行为意愿，因此意见领袖的关系强度主要是通过展示红色旅游目的地的信息时候展示的个人魅力。

基于此，本文提出假设

H11:意见领袖的关系强度会对红色旅游消费者的行为意愿产生正向影响。

3.12 产品涉及与行为意愿

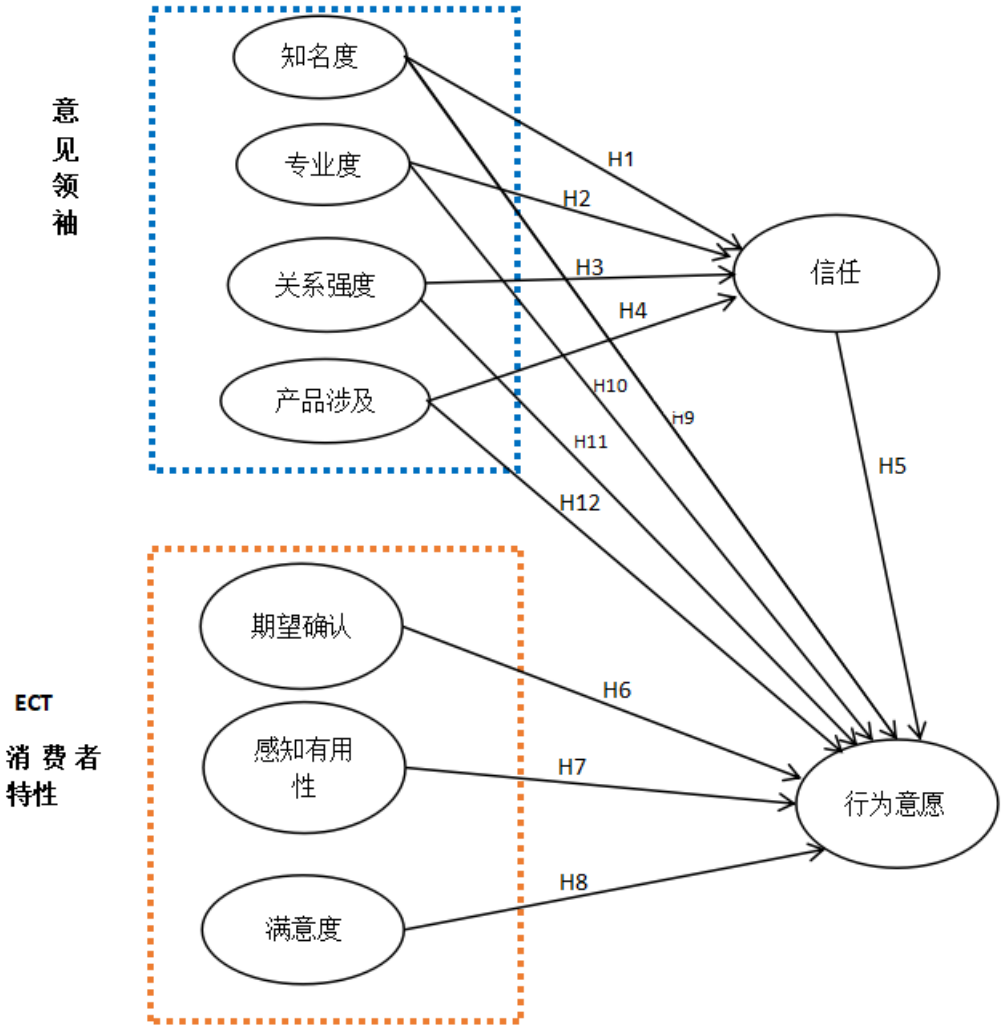
产品涉及(Products involved)主要反应了人与人的交往和沟通，如 Ghose 等(1998)将其定义为可以直接接触互动沟通信息的能力[39]。互动性属于意见领袖的社会属性。包旭(2012)认为网络意见领袖的互动性促进社会沟通，有利于信息自由流通[40]。彭振等（2019）实证分析表明在线评论对线上购买旅游产品有显著的正向影响[41]。肖开红等（2021）研究发现，网络社区中的用户交互行为能够提高用户的可信度[42]。现在的互联网已经不是那种虚幻的虚拟世界了，旅游行业的领袖们可以利用短视频平台，不断的发布自己想要去哪里的地方，让自己的粉丝有一种和自己的好朋友在一起旅行的错觉。如范小军等(2020）从心理学的角度，研究了交互对使用者的持续使用意向的影响机制[43]。因此，本文认为，意见领袖的影响对象是大学生红色旅游的目的地行为意愿，即意见领袖与大学生红色旅游游客之间的交互作用。

基于此，本文提出假设

H12:意见领袖的产品涉及会对红色旅游消费者的行为意愿产生正向影响。

(二) 模型构建

根据上述文献综述及理论基础，结合 ECT 模型和意见领袖理论，现构建本文理论模型如下：



（图 3—— 本研究模型假设）

四、调查设计

（一）量表设计

本文在对国内外学者的研究成果和文献整理的基础上，对意见领袖、期望确认、行为意愿等因素进行了分析。下面的表格显示了研究的变量。

最后的量表是在查阅了大量国内外高品质的学术研究量表后才得以形成，以保证量表的科学性和精确度。本研究的问卷调查均为单选题，采用李克特五点记分法，由 1 至 5 的程度逐步加深，1 为非常不赞同，5 为非常赞同。此外，为确保测验的效度，每一项测验都设有 3 个或更多的题目。

编号	变量	测量量表	指标来源
1	期望确认度	1.听取意见领袖的意见后，我发现比我期望的要好。	Bhattacherjee(2001)
2		2.该嘉兴南湖旅游提供的服务比我期望的要好。	
3		3.意见领袖对嘉兴南湖旅游的服务给我带来的益处大于我的预期。	
4		4.总的来说，我对该嘉兴南湖旅游的期望在使用过程中得到了满足。	
5	感知有用性	1.通过意见领袖能获得我想要的信息。	Vankatesh(2003)、Davis(1989)
6		2.意见领袖提高了旅游的效率，对我十分有帮助。	
7		3.总的来说，我觉得意见领袖对我很有用。	
8	满意度	1.在浏览该意见领袖推荐的嘉兴南湖短视频后，嘉兴南湖让我感到很愉悦。	Oliver(1980)、Sweeney&Soutar、谢雪娇（2021）
9		2.我很喜欢意见领袖推荐的嘉兴南湖短视频后，嘉兴南湖让我心生憧憬。	
10		3.在浏览意见领袖推荐的嘉兴南湖视频后，我觉得嘉兴南湖是个出游好去处。	
11	持续使用意愿	1.听了意见领袖的建议后，我很有可能会选择去嘉兴南湖。	Bhattacherjee(2001)、Kim(2011)
12		2.我愿意长期听取意见领袖的建议。	
13		3.我愿意向亲戚朋友推荐意见领袖。	
14	知名度	1.我可以很容易识别出嘉兴南湖与其他旅游地点的不同	YOO&Donthu(2001)、梦非(2012)
15		2.当我想到红色旅游时，我会首先想到嘉兴南湖	
16		3.我能时刻想起嘉兴南湖是中国共产党的诞生地	
17		4.嘉兴南湖是家喻户晓的	
18		5.我了解嘉兴南湖	
19	专业度	1.该意见领袖在嘉兴南湖领域具备相关知识	Engel(1995)、朱茂然(2017)
20		2.该意见领袖在嘉兴南湖拥有专业能力	
21		3.该意见领袖在嘉兴南湖经过专门训练	
22		4.该意见领袖在嘉兴南湖的实践经验十分丰富	
23	关系强度	1.我感受到该意见领袖与我个性相似	Gilly(1998)、(Rogers et al.2003)
24		2.我认为该意见领袖与我品位相同	
25		3.我认为该意见领袖对嘉兴南湖的价值观和认知与我相同	
26		4.我认为该意见领袖喜欢的这类产品和我的兴趣在相似领域	
27	产品涉及	1.该意见领袖平时非常关注嘉兴南湖	Zaich kowsky(1985)、刘海群(2015)
28		2.该意见领袖平时非常喜欢嘉兴南湖	
29		3.我能感觉出嘉兴南湖与意见领袖很合适	
30		4.我能感觉出该意见领袖对嘉兴南湖十分看重	
31		5.我能感觉出意见领袖将大部分时间和心思都花费在嘉兴南湖	
32	信任	1.我相信意见领袖发布的产品信息不含虚假成分	Mayer(1995)
33		2.我相信该意见领袖就有发布高专业度信息的能力	
34		3.我相信该意见领袖在产品的信息传达方面是诚实的	
35		4.我相信该意见领袖推荐嘉兴南湖信息的目的之一是为了帮助他人了解嘉兴南湖进而做出正确的购买决策	

（表 1——本研究量表）

（二）问卷调研

本文的研究对象为上海大学生。因为网络问卷不受时间和地点的限制，具有便捷和高效的特点，所以本文采用网络问卷的形式发放。本人于 2022 年 7 月 30 日——8 月 30 日　间使用问卷星官网设置好问卷，并通过 QQ、微信等社交软件发放问卷。

本次调研共回收 333 份调研问卷，其中有效问卷 300 份，有效回收率为 90 %。

五、资料分析

1.样本分布情况

本研究 333 份问卷填写者的基本资料分析如表 2 所示。男性（161 人）48.35%，女性（172 人）51.65%；年龄小于 18 岁的有 47 人（14.11%），18 岁—25 岁的有 239 人（71.77%），26 岁—35 岁的有 34 人（10.21%），36 岁以上的有 13 人（3.9%）；学历在初中及以下的有 20 人（6.01%）、高中或中专学历的有 31 人（9.31%）、本科或大专的有 220 人（66.07%）、本科以上的有 62 人（18.62%）；职业为公务员/机关事业单位职员的有 12 人（5.0%）、公司职员的有 42 人（17.4%）、学生有 253 人（75.98%）、其他职业有 1.62%。

2.信度分析

信度分析也就是可靠性分析，只有量表具备较高的信度水平，所收集到的数据才具有分析价值，才能得到科学与真实的问卷结果。在信度的检验上，常用 Cronbanch α 系数的大小来衡量，当该系数越接近于+1 时，量表的信度越高。DeVeill（1991）认为信度检验值在 0.7 以上为可接受值[44]。通常而言，α 系数大于 0.9 说明量表信度极佳；α 系数在 0.8-0.9 之间表明量表具有较好的信度；α 系数在 0.7-0.8 之间则意味着量表通过检验，信度在可接受的范围内；而当 α 系数小于 0.7 时，则需要重新修订量表。本研究的量表信度分析结果如表 2 所示：

表 2 信度分析表

维度	问项代码	项目 Cronbach Alpha	Cronbach Alpha	基于标准化项目的 Cronbach Alpha	Cronbach Alpha	基于标准化项目的 Cronbach Alpha
期望确认度	Q15	0.969	0.969	0.969	0.973	0.973
	Q16	0.970				
	Q17	0.969				
感知有用性	Q12	0.969	0.969	0.969		
	Q13	0.969				
	Q14	0.969				
持续使用意愿	Q18	0.968	0.969	0.969		
	Q19	0.969				
	Q20	0.969				
知名度	Q21	0.968	0.969	0.969		
	Q22	0.969				
	Q23					
	Q24	0.969				
	Q25	0.969				
专业度	Q34	0.968	0.969	0.969		
	Q35	0.969				
	Q36	0.968				
	Q37	0.969				
关系强度	Q26	0.968	0.969	0.969		
	Q27	0.969				
	Q28	0.968				
	Q29	0.969				
信任	Q38	0.969	0.969	0.969		
	Q39	0.969				
	Q40	0.968				
	Q41	0.969				
	Q42	0.969				

从上表可知：信度系数值为0.969，大于0.9，因而说明研究数据信度质量很高。综上所述，研究数据信度系数值高于0.9，综合说明数据信度质量高，可用于进一步分析。

2.效度分析

效度分析简而言之就是测量结果的有效性。1981 年 Fornell & Larcker 认为若同时满足下列三项指标则判定测量模型具有收敛效度：问项的因素负荷量必须超过 0.7 且于 t 检验时显著；潜在变量组合信度 CR 值必须大于 0.6，数值越高意味着维度具有越高的内部一致性；每个维度的平均变异萃取量必须大于 0.5[45]。

维度	问项代码	标准化因素负荷量	P	SMC	CR	AVE
专业度	Q1-1	0.984	***	0.968	0.883	0.606
	Q1-3	0.719	***	0.517		
	Q1-4	0.722	***	0.521		
	Q1-5	0.717	***	0.514		
信任	Q2-1	0.768	***	0.590	0.260	0.634
	Q2-2	0.729	***	0.531		
	Q2-3	0.739	***	0.546		
	Q2-4	0.932	***	0.869		
行为意愿	Q3-1	0.759		0.576	0.777	0.539
	Q3-2	0.654	***	0.428		
	Q3-3	0.783	***	0.613		
关系强度	Q4-1	0.962	***	0.925	0.902	0.650
	Q4-2	0.797		0.635		
	Q4-3	0.767	***	0.588		
	Q4-4	0.749	***	0.561		
	Q4-5	0.736	***	0.542		
感知有用性	Q5-1	0.947	***	0.897	0.283	0.675
	Q5-2	0.782		0.612		
	Q5-3	0.789	***	0.623		
	Q5-4	0.754	***	0.569		
期望确认度	Q6-1	0.923	***	0.852	0.260	0.634
	Q6-2	0.743		0.552		
	Q6-3	0.786	***	0.618		
	Q6-4	0.717	***	0.514		
知名度	Q7-1	0.923	***	0.852	0.899	0.600
	Q7-2	0.729	***	0.531		
	Q7-3	0.762	***	0.581		
	Q7-4	0.714	***	0.510		
	Q7-5	0.739		0.546		
	Q7-6	0.762	***	0.581		

表 6 收敛效度分析表

注：***T＞3.29，**T＞2.58，*T＞1.96

从表 6 可知，本研究量表所有因素负荷量皆大于 0.7 且显著；潜在变量组合信度 CR 值除了 Q2、Q3、Q5、Q6 问项的 CR 值没有达到 0.8，其余都是介于 0.883—0.902 之间；除了 Q3 没有到 0.6，其余各个维度的平均变异萃取量介于 0.600—0.675 之间。同时满足了以上三项指

标的理想值，这表示同一潜在维度的所有测量问项彼此之间的相关值很高，也就是说本研究测量模型具有收敛效度。

然而，除了分析收敛效度还需要分析区分效度。1998 年 Hair 等人建议潜在维度的平均变异萃取量的平方根值应大于特定潜在维度与其他维度之间的相关系数，则维度间具有区分效度[53]。本研究的区分效度分析结果如表 7 所示。

表 7 区分效度分析表

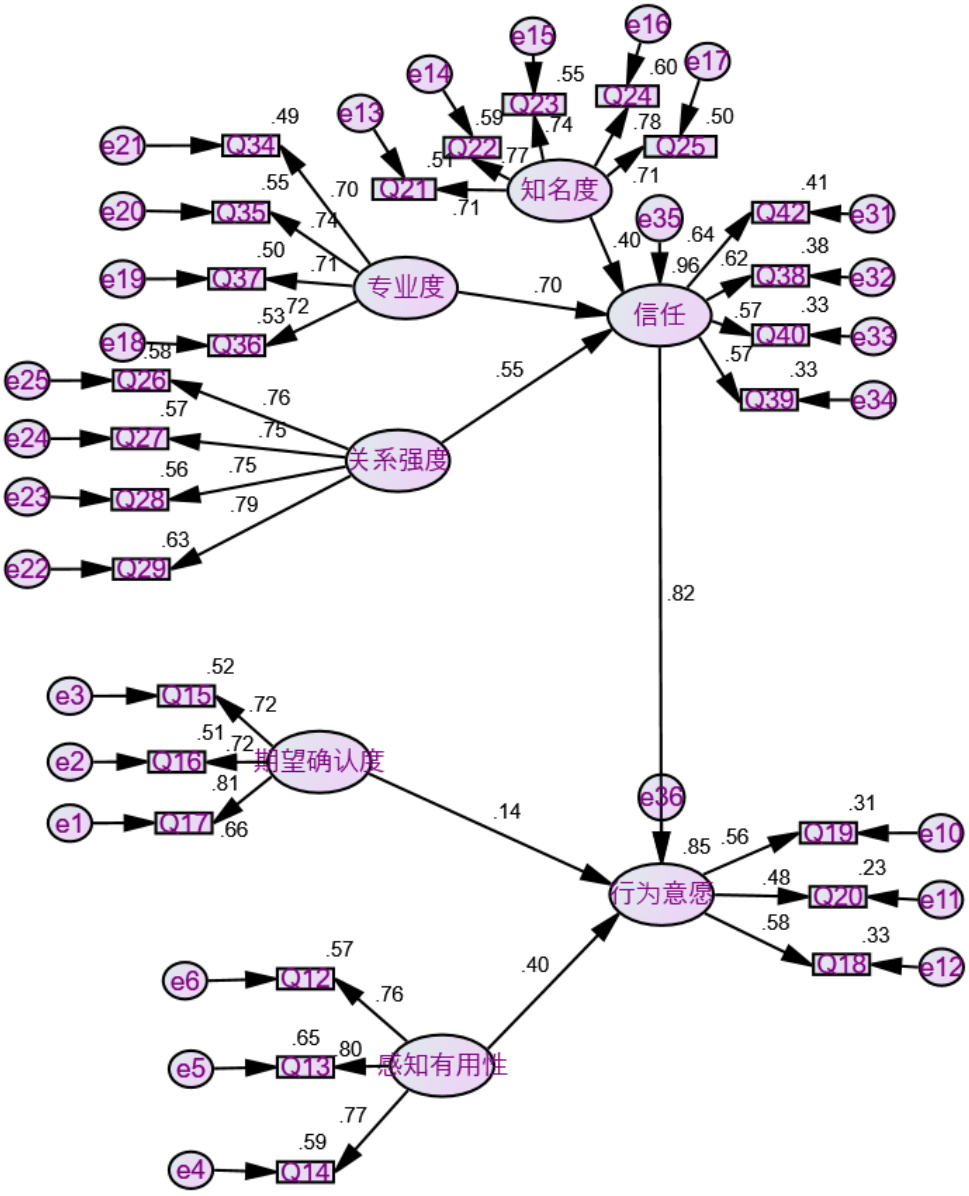
	AVE	关系强度	专业度	知名度	感知有用性	期望确认度	信任	行为意愿
关系强度	0.650	**0.806**						
专业度	0.606	0.000	**0.779**					
知名度	0.600	0.000	0.000	**0.775**				
感知有用性	0.675	0.000	0.000	0.000	**0.822**			
期望确认度	0.634	0.000	0.000	0.000	0.000	**0.796**		
信任	0.634	0.248	0.292	0.166	0.000	0.000	**0.796**	
行为意愿	0.539	0.185	0.218	0.124	0.165	0.059	0.217	**0.734**

注：对角线上的数值（粗字体）代表平均变异萃取量的平方根，非对角线上的数值则为各构面间的相关系数。

本研究潜在维度的平均变异萃取量的平方根值最小数值为0.734，除满意度与持续使用意愿的相关系数外均高于其他两两维度之间的相关系数，这说明本研究各潜在维度之间具有良好的区分效度。

（三）结构模型分析

图 4——本研究模型路径图



Chi-square=2267.165 DF=293 Chi/DF=7.738
GFI=.626 AGFI=.552 RMSEA=.142

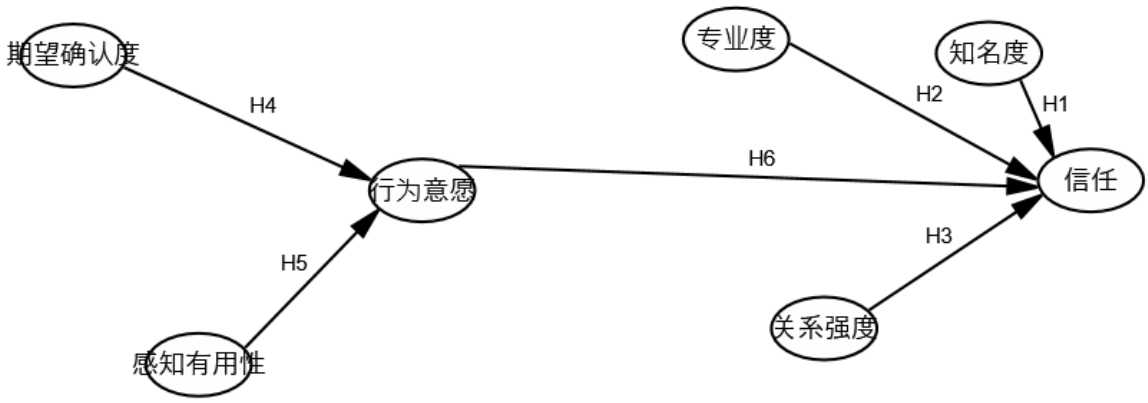


图 5——模型标准化路径系数图

3.1 路径检验

路径检验是为得到研究模型中各个变量间的相关关系，并验证这些系数的显著性概率。本文使用 AMOS 软件，结合本研究模型，对各变量进行路径检验，检验结果如表 9 所示。

表 4　结构模型路径检验表

路径	路径系数	标准误差	T 值	P 值
专业度→信任	0.700	0.044	1.638	***
知名度→信任	0.400	0.050	1.821	***
关系强度→信任	0.550	0.074	2.803	***
信任→行为意愿	0.820	0.028	1.261	***
期望确认→行为意愿	0.140	0.079	3.073	***
感知有用性→行为意愿	0.400	0.044	1.629	***

注：***P＜0.001，**P＜0.01，*P＜0.05

所有路径皆达到显著性水平，结构模型路径分析系数为：（1）知名度对信任的路径系数为 0.400。（2）专业度对信任的路径系数为 0.700。（3）关系强度对信任的路径系数为 0.550。（4）期望确认度对行为意愿的路径系数为 0.140。（5）感知有用性对行为意愿的路径系数为 0.400。（6）信任对行为意愿的路径系数为 0.820。

4. 实证结果及分析

通过上述路径分析图可判断出本研究模型所提出的研究假设成立情况，结果如下表 3 所示。

编号	假设	检验结果
H1	意见领袖的知名度会对红色旅游消费者的信任有正向影响	成立
H2	意见领袖的专业度会对红色旅游消费者的信任有正向影响	成立
H3	意见领袖的关系强度会对红色旅游消费者的信任有正向影响	成立
H4	期望确认对红色旅游消费者的持续使用意愿有正向影响	成立
H5	感知有用性对红色旅游消费者的持续使用意愿有正向影响	成立
H6	信任对红色旅游消费者的持续使用意愿有正向影响	成立

表 5 研究假设检验结果

（1） 意见领袖的知名度、专业度、关系强度对红色旅游消费者的信任产生正向影响作用。

根据上文的研究结果，消费者的信任受到意见领袖的 、专业度、关系强度三个维度的显著正向影响，假设 1、假设 2、假设 3 均得到支持。知名度对信任的正向影响与孟非等学者的研究结论相一致。专业度对信任的正向影响与朱茂然等学者的研究结论相一致。关系强度对信任的正向影响与 Bower 等学者的研究结论相一致。

知名度（r=0.400，p＜0.001）对红色旅游消费者的信任有显著正向影响，并通过对意见领袖的知名度间接影响消费者的信任，假设 1 得到支持。说明意见领袖有较高的名气、专业性很强、被大众熟知，因此，他们的观点容易被人们知晓和被消费者相信和追随，进而间接提高红色旅游消费者的信任。

专业度（r=0.700，p＜0.001）对红色旅游消费者的信任有显著正向影响，并通过对意见领袖的专业度间接影响消费者的信任，假设 2 得到支持。说明具有较高专业能力的信息传播者的意见更容易被消费者青睐和采纳，专家发出的信息可以对购买决策产生至关重要的影响，进而间接提高红色旅游消费者的信任。

关系强度（r=0.550，p＜0.001）对红色旅游消费者的信任有显著正向影响，并通过对意见领袖的专业度间接影响消费者的信任，假设 3 得到支持。说明具备强吸引力特征的人更容易使消费者产生可靠的感知，进而间接提高红色旅游消费者的信任。

（2） 期望确认、感知有用性、信任对红色旅游消费者的持续使用意愿产生正向影响作用。

期望确认（r=0.140，p＜0.001）对红色旅游消费者的持续使用意愿有显著正向影响，并通过对意见领袖的期望确认间接影响消费者的持续使用意愿，假设 4 得到支持。期望确认对红

色旅游消费者的持续使用意愿有显著正向影响与 Bhattacherjee 等学者研究结论相一致。说明消费者得到的服务比预期要高时候，进而会间接提高红色旅游消费者的持续使用意愿。

感知有用性（r=0.400，p＜0.001）对红色旅游消费者的持续使用意愿有显著正向影响，并通过对意见领袖的期望确认间接影响消费者的持续使用意愿，假设 5 得到支持。感知有用性对红色旅游消费者的持续使用意愿有显著正向影响与陈宣文研究结论相一致，说明消费者会对将为此产品支付的成本和获取的收益进行综合性的对比和感知，所以顾客会优先购买他们认为感知价值最大的产品，感知有用性会进而间接提高红色旅游消费者的持续使用意愿。

信任（r=0.820，p＜0.001）对红色旅游消费者的持续使用意愿有显著正向影响，并通过对意见领袖的期望确认间接影响消费者的持续使用意愿，假设 6 得到支持。信任对红色旅游消费者的持续使用意愿有显著正向影响与 Mayer 等学者研究结论相一致。说明，红色旅游消费者对意见领袖的无条件接受的信赖，进而间接提高红色旅游消费者的持续使用意愿。

六、研究建议

基于上述研究结果，本研究为旅游业如何提高红色旅游消费者的持续使用意愿，提出以下几条建议：依据本研究的研究结果，信任到持续使用意愿的路径回归系数为 0.82，表示有强信任的人就会有很高的持续使用意愿，知名度、专业度、关系强度会影响信任，所以我们可以从以下三个方面提高红色旅游消费者的持续使用意愿：

1. 提高红色旅游景区的知名度

本研究结果显示，信任到持续使用意愿的路径回归系数为 0.82，表示有强信任的人就会有很高的持续使用意愿，知名度到信任的路径回归系数为 0.40，说明对红色旅游消费者的信任有显著正向影响，并通过对意见领袖的知名度间接影响消费者的信任。说明意见领袖有较高的名气、专业性很强、被大众熟知，因此，他们的观点容易被人们知晓和被消费者相信和追随，进而间接提高红色旅游消费者的信任。

所以，企业应该请在红色旅游景区有影响力的意见领袖做宣传，品牌的良好和良好的信誉是公司成功发展的基础，企业在进行品牌策划、品牌概念设计、品牌文化展示、塑造品牌形象等方面，并在以后的各种广告宣传活动中加强用户对品牌、品牌标志和设计的管理。目前，各行各业的商家都可以通过抖音、微博等网络平台来提升自己的品牌知名度，但不管是通过电视广告、网络等传统媒体，或是通过网络等媒介进行广告宣传，商家都必须根据消费

者的需要，制定自己的产品营销战略，这样才能赢得更多的消费者支持，从而在激烈的市场竞争中存活下来。

2. 夯实高质量人才的专业度

本研究结果显示，信任到持续使用意愿的路径回归系数为 0.82，表示有强信任的人就会有很高的持续使用意愿，专业度（r=0.700，p＜0.001）对红色旅游消费者的信任有显著正向影响，并通过对意见领袖的专业度间接影响消费者的信任。说明具有较高专业能力的信息传播者的意见更容易被消费者青睐和采纳，专家发出的信息可以对购买决策产生至关重要的影响，进而间接提高红色旅游消费者的信任。

因此，红色旅游企业要重视后备干部的训练，要对干部的训练方式进行改革。结合我省发展特点，结合全省工业发展需要，与党校等单位紧密协作，在全国范围内进行“红色旅游”专业建设，成立嘉善南湖红色旅游研究院；要加强校企等领域的合作，加强对人才的培养和输送。在管理、规划、运营管理等方面，要进一步强化旅游管理、规划、运营管理等方面的管理、规划、运营管理，明确薪酬与发展机会，提升旅游人才的综合素质。嘉善旅游导游队伍建设，旅游导游服务管理模式，开发嘉善红色旅游景点解说词，构建符合新时期发展要求的导游语言体系；引进了现代元素，使人们的认知发生了变化。要增强全省群众红色旅游主体意识，促进群众参与红色旅游开发保护，积极支持退伍军人、离退休老干部等群体投入红色精神和故事的讲解工作，引导红色旅游项目为省内困难群众、低收入群体提供培训和就业岗位。

3. 完善嘉善红色旅游产业机制

本研究结果显示，信任到持续使用意愿的路径回归系数为 0.82，表示有强信任的人就会有很高的持续使用意愿，关系强度（r=0.550，p＜0.001）对红色旅游消费者的信任有显著正向影响，并通过对意见领袖的专业度间接影响消费者的信任。说明具备强吸引力特征的人更容易使消费者产生可靠的感知，进而间接提高红色旅游消费者的信任。

健全相关法律法规和制度，促进红色旅游的健康发展。要进一步明确发展红色旅游的制度，完善红色产业发展的管理制度，强化红色旅游的开发与传承。加强组织协调、管理和领导，推进红色旅游制度的改革，健全红色教育、红色教育、红色精神传承、部门治理、游客管理应急机制，促进浙江省红色旅游发展的创新。要健全公民参与机制，加强企业、科研单位和个人的参与，完善健全的激励机制。

七、不足与展望

本研究模型的路径 GFI 和 AGFI 的适配度不是很好，可能是由于问卷填写方面的差异回答，每个人回答的都不一样，导致模型适配度不高；问卷数量不是很大，只收集了 333 份问卷，如果有机会，后续还会完善问卷，提高问卷质量和数量。

附录（一）问卷设计

尊敬的女士/先生:

您好!这是关于一份关于意见领袖(Key Opinion Leader,以下简称 KOL,作为新时代的一种标杆，能够影响到许多人对某种东西的看法)影响大学生红色旅游计划重要因素调查，本研究的内容主要在于探讨意见领袖的哪些因素会影响大学生对红色旅游计划的决策。本调查采取匿名方式，您所填的资料将仅供学术分析研究使用，不作个别披露或其他用途，请放心作答。

以下有关您的个人资料，仅供学术统计分析之用。绝对保密，敬请放心作答。

1、您的性别
2、您的年龄
3、您目前从事的职业：
4、您的学历
5、您有没有嘉兴南湖经历？
6、您有没有嘉兴南湖旅游意愿？
7、如果您有嘉兴南湖旅游意愿，您是否制定了嘉兴南湖旅游计划？
8、您的平均月消费水准？
9、听取意见领袖的意见后，我发现比我期望的要好？
10、意见领袖对嘉兴南湖旅游的服务给我带来的益处大于我的预期？
11、总的来说，我对该嘉兴南湖旅游的期望在使用过程中得到了满足？
12、通过意见领袖能获得我想要的信息？
13、意见领袖提高了旅游的效率，对我十分有帮助？
14、总的来说，我觉得意见领袖对我很有用？
15、在浏览该意见领袖推荐的嘉兴南湖短视频后，嘉兴南湖让我感到很愉悦？
16、我很喜欢意见领袖推荐的嘉兴南湖短视频后，嘉兴南湖让我心生憧憬？
17、在浏览意见领袖推荐的嘉兴南湖视频后，我觉得嘉兴南湖是个出游好去处？
18、听了意见领袖的建议后，我很有可能会选择去嘉兴南湖？
19、我愿意长期听取意见领袖的建议？
20、我愿意向亲戚朋友推荐意见领袖？
21、我可以很容易识别出嘉兴南湖与其他旅游地点的不同　？
22、当我想到红色旅游时，我会首先想到嘉兴南湖？
23、我能时刻想起嘉兴南湖是中国共产党的诞生地？
24、嘉兴南湖是家喻户晓的？
25、我了解嘉兴南湖？
26、该意见领袖在嘉兴南湖领域具备相关知识？
27、该意见领袖在嘉兴南湖拥有专业能力？
28、该意见领袖在嘉兴南湖经过专门训练？

29、该意见领袖在嘉兴南湖的实践经验十分丰富？

30、我感受到该意见领袖与我个性相似？

31、我认为该意见领袖与我品位相同　　？

32、我认为该意见领袖对嘉兴南湖的价值观和认知与我相同　　？

33、我认为该意见领袖喜欢的这类产品和我的兴趣在相似领域？

34、该意见领袖平时非常关注嘉兴南湖　？

35、该意见领袖平时非常喜欢嘉兴南湖　？

36、我能感觉出嘉兴南湖与意见领袖很合适　？

37、我能感觉出该意见领袖对嘉兴南湖十分看重？

38、我能感觉出意见领袖将大部分时间和心思都花费在嘉兴南湖？

39、我相信意见领袖发布的产品信息不含虚假成分？

40、我相信该意见领袖就有发布高专业度信息的能力？

41、我相信该意见领袖在产品的信息传达方面是诚实的　　？

42、我相信该意见领袖推荐嘉兴南湖信息的目的之一是为了帮助他人了解嘉兴南湖进而做出正确的购买决策？

致谢

在本论文完成之际，谨向我的指导老师谢淑慈老师表示感谢，从论文开题到定稿的几个月来给予我耐心的指导和帮助，提出宝贵的修改意见并细致地检查我论文中的错误，从老师身上我学到了严谨认真的学术态度，并发现了自身的许多不足。

一朝沐杏雨，一朝念师恩。感谢谢老师对我论文的指导与帮助，对我完成论文起到了很大的帮助。感谢谢老师的包容与耐心，解答我的困惑，让我完成我的论文。愿恩师桃李芬芳，教泽绵长。感谢管理学院所有的任课老师，他们的人格魅力和谆谆教诲我将铭记在心，感谢谢老师作为导师对我的帮助和指导，同时感谢管理学院所有的行政老师们，是他们让我的学习生活不再有后顾之忧。

树高千尺不忘根深沃土。感谢我的父母家人，我们的一生在于无数人相逢，唯有父母从出生就在分别。在此感谢我的父母，在我过去二十多年对我的爱与支持。感谢父母用碎碎念念温暖我的生活，愿你们岁岁年年皆平安。感谢我的父母一直在我背后的支持和鼓励，感谢舍友四年来的陪伴，感谢 B210521 班所有一路同行的同学们，这会是我人生中宝贵的回忆。

酒店管理专业是理性和感性的交织，教会我严谨，也教给我感动。四年时光转瞬即逝，有许多快乐，也有许多遗憾。毕业不是终点，愿大家都有一个美好的未来。青春读书处，永远一家人。

以梦为马，不负韶华。最后希望以后的自己可以努力的爱与生活。

行文终有收笔时，感恩所有经历，感恩所有遇见，向未来张望时，或许孤独又漫长，希望努力过后，皆是晴朗。

2022 年 9 月 3 日

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A trimming-based innovative design method using patent knowledge to mine system resource

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Abstract

Trimming is a design method for product improvement that solves problems by bypassing current problems and helps products obtain more smart solutions by mining and utilizing system resources. Due to the limitations of designer's own knowledge and design fixation, mining the available resources effectively for system function reorganization is the main obstacle of the trimming method. Therefore, a trimming-based innovative design method using patent knowledge to assist system resource mining is proposed. First, according to the logic of screening first, classification later, and sorting finally, a multi-level retrieval strategy of target patent based on multi-dimensional retrieval features is formed, which realizes the precise recommendation of patent knowledge effectively. Secondly, based on the Structure Mapping Theory (SMT), a specific patent knowledge analogy mapping process is formed, which can help designers to complete the fine-grained system resource mining under the condition of complex external attributes to realize the redistribution of useful functions in system. The proposed method reduces the requirement for the designer's own knowledge level in the use process, effectively breaks the design fixation, and improves the production efficiency of the high-quality specific design scheme in trimming. Finally, the superiority of the method was verified by comparative experiments.

Keywords: Patent knowledge recommendation, Structure Mapping Theory (SMT), System resource mining, Trimming

1. Introduction

Trimming accomplishes product innovation by removing harmful or redundant components from the system and making full use of in-system or super-system resources for useful functional reorganization (Tan, 2020). It is characterized by simplifying the system structure, reducing cost and improving system's idealization while achieving innovation of product. However, in the actual promotion and application, it is found that there are few high-quality innovative design solutions in trimming. The reason is that it is difficult for designers to find available resources in the system to complete the process of redistributing useful functions of the system after removing system components.

Currently, the implementation of trimming method mainly includes two phases, identification of components that can be trimmed and reorganization of useful functions in system (Yu, et al., 2015). The trimming rules can guide designers to quickly activate their knowledge and complete the function redistribution process (Sheu and Hou, 2015). However, on the one hand, the designer's own knowledge has limitations. On the other hand, people usually prioritize what they already know (subjective knowledge). Therefore, the innovative design process is limited by design fixation (Jansson and Smith, 1991).

Based on the above research, it is necessary to assist designers to reorganize useful functions with the help of external knowledge. There are two types of external knowledge, one is objective knowledge as highly generalized as the principle of invention in TRIZ, Abstract knowledge is more likely to inspire designers to innovate, but rich and detailed knowledge is better at practicality (Cheng, et al., 2014). The other category is specific knowledge such as patents. The technology is represented as material characteristics or component in the patent text, which is a microlevel expression (Choi, et al., 2013). Therefore, the advantages of patent knowledge lie in the specificity, visualization, and multiple external attributes, which can make the analogy mapping process more specific, facilitate the breaking of design fixation, and reduce the requirements for the designer's own knowledge level. However, the huge volume of its knowledge base and there are too many specific external attributes contained in knowledge individuals. Therefore, how to achieve precise matching between specific external knowledge and design problems, and how to achieve analogy mapping under complex external attribute conditions to complete knowledge transformation are the key issues to be solved.

Focusing on research related to Chinese patents, a trimming-based innovative design method using patent knowledge to mine system resource is proposed.

2. Related work

▪2.1 Useful function reorganization methods in trimming

There have been many studies on functional reorganization methods useful in trimming. Yeoh (2009) proposed three useful function reorganization rules around the role relationship between components, but lack knowledge guidance. The computer-aided innovation software TechOptimizer provides four useful function reorganization rules based on the functions of components to be trimmed (Zhu, 2003). On this basis, Sheu and Hou (2015) expands and organizes it into six trimming rules based on the trimming innovative goal, which strengthens the pertinence of trimming rules in use. To overcome the limitations of designer's own knowledge in analysis process, knowledge-inspired methods for reorganizing useful functions of systems have been proposed (Yu, et al., 2015). TRIZ tools such as invention principles and technological evolutionary trends are used to assist in the reorganization of useful functions in the system and have formed corresponding selection strategies (Zhang, et al., 2018, Shi, et al., 2016). However, the acquisition of resources is not directly related to function model of the trimmed system, so it is not conducive to the optimal configuration of the system resources. Bai, et al. (2020) used standard solutions to assist system resource mining for realizing useful function reorganization in trimming. But the analysis and selection process of standard solutions was complicated.

Although objective knowledge such as inventive principles can quickly provide designers with inspiration for problem solving, these creative principles are typically expert schemas (Liu, et al., 2019). They are highly generalized in expression, which is not conducive to breaking the design fixation.

▪2.2 Patent text mining

It has become increasingly important to complete patent analysis and discover relevant technical information using various techniques and tools (Abbas, et al., 2014). In patent information extraction, Fantoni, et al. (2013) realized the automatic extraction of function-behavior-state (FBS) information in patents with the help of natural language processing (NLP) combined with the FBS model. Ma, et al. (2019) proposed a compound efficacy phrase extraction process based on rules and conditional random fields to extract efficacy information in Chinese patent texts from an efficacy perspective. Choi, et al. (2012) proposed a text mining method based on a subject-operation-object (SAO) structure and used this method to extract and analyze the SAO structure from patent documents to form a technology tree for technology planning. In terms of patent knowledge to assist product innovation, Ma, et al. (2021) used a patent clustering method based on efficacy features to obtain cross-domain patents for product innovation. Liu, et al. (2020) developed a cross-domain patent retrieval tool with the help of a semisupervised learning algorithm to label patent data with function information, a K-means algorithm to achieve technology clustering, and domain attributes to achieve patent evaluation. The concept of the SAO structure originated from TRIZ (Choi, et al., 2013) and is also a research focus in the field of textual information mining. In the SAO structure, if AO (action-object) describes a technical problem and S (subject) represents a solution, then it can be interpreted as a relationship between the problem and the solution (Moehrle, et al., 2005). And, the open-source natural language processing tools such as Harbin University

Language Technology Platform (LTP) is popular to be used to extract SAO structure of Chinese patent documents (LTP, 2021).

The above studies illustrate that the patent text information contains function, efficacy, technology, and structure, which provide a basis for retrieving the target patents from multiple perspectives. The expression of the function model in the function analysis can be mapped to the SAO structure. So, the expression form of the SAO structure is the bridge of technical information mapping between the trimmed system and the patent text.

▪2.3 Resource, structure, attribute and the relationships among them

In TRIZ, resources refer to inventive resources used in the inventive process and anything that can be used to achieve desirable functions or values, whether they are tangible or intangible (Sheu and Yen, 2020). Based on the difficulty of obtaining resources, resources can be divided into internal resources, external resources, and resources in the super system; Based on whether they can be used directly, resources can be divided into directly applicable resources and derived resource (Bai, et al., 2020). To prioritize using in-system or super-system resources as much as possible to accomplish useful functional reorganization, the concept of context features is proposed from the perspective of resource consistency between the target patent system and the trimmed system. The relevance of the context feature between the trimmed system and the target patent is an important basis for determining the priority of patent literature selection within a patent set.

Structural mapping theory (SMT) includes structural relations and element features and emphasizes the importance of structural relations (Gentner, 1983). SMT has been applied in the field of engineering design; for example, effect knowledge is mapped to engineering problems to obtain solutions with the help of SMT (Wang, et al., 2021). SMT-based knowledge representation (Liu, et al., 2019), structural knowledge in biological phenomena is transferred by analogy to accomplish bionic design (Cheong and Shu, 2013). Wang (2017) pointed out that structure mapping refers to the relationships between elements (e.g., causal, topological, etc.) and functional or formal relationships. Therefore, the structure should specifically include the structural relationships between entities and the functional or formal characteristics of individual entities. According to the view that "similar problems have similar solutions (Sheu and Chiu, 2017)", mapping the structural relationships between the target patents and the problematic areas in the trimmed system can give designers knowledge inspiration from the perspective of structural relationships. In addition, through the attribute analysis of resources, the fine-grained system resource mining is completed from the attribute level.

Different scholars have different understandings on attributes. Umeda, et al. (1999) consider that the attribute is a certain recognizable character possessed by a material. Zhao (2016) believes that attributes are the essential and inevitable characteristics of matter. Matter and function are connected through attributes. Function is usually the result of the interaction between the attributes

of two matters. Bai, et al. (2020) expanded the attribute list and divided them according to application fields. Part of the attribute list is shown in Table 1. When analyzing attributes, the importance of different attributes is often overlooked if only the resource is judged to have the attribute or not. So, the attributes are classified into basic and auxiliary attributes based on their importance. With reference to the Likert scale, the evaluation criteria for the basic and auxiliary attributes are formed, as shown in Table 2.

Table 1. List of resource attributes (Bai, et al., 2020)

Attribute Classification	Detailed content
Physical attributes	Phase state, temperature, color, humidity, …
Geometric attributes	Shape, angle, length, width, …
Material attributes	strength, hardness, fluidity, insulation, …
Process attributes	Flexibility, stretchability, severability, …
Chemical attributes	Metallic, nonmetallic, acidic, alkalinity, …

Table 2. Attribute evaluation criteria

Attribute level	Extremely important basic attribute	Extremely important auxiliary attribute	Important basic attribute	Important auxiliary attribute	Generally, important basic/auxiliary attributes
Valuation	1	0.8	0.6	0.4	0.2

3. Proposed method

▪3.1 Identification of target patents

(1) Identify the retrieval features of the target patent

Based on an in-depth analysis of the trimmed system space and patent knowledge space, the multidimensional retrieval features of the target patents can be identified. The multilevel feature mapping relationship between the trimmed system space and the patent knowledge space is shown in Figure 1.

Firstly, the function and efficacy features (For example, functional features include separation, movement, etc., and functional features include fire protection, firmness, etc.) are extracted for the design goal. The reasons are as follows: Function similarity is a prerequisite for design knowledge transfer (Jia, et al., 2019). Meanwhile, the undesirable efficacy of the trimmed system should be avoided or reduced in the target patent. Therefore, the desired efficacy is taken as one of the retrieval features. Secondly, since the trimming method aims at using in-system or super-system resources that have existed in the trimmed system to realize the objective function or efficacy, technical and situational features should be extracted. To ensure this, it is required that the components performing the main functions and the material, energy, and signal resources in the selected target patents are as similar as possible to that of the trimmed system. Therefore,

the components that perform the main functions are used as technical features, and the material, energy, and signal resources are used as context features. The two together serve as the target patent retrieval features for the trimming method, ensuring that the retrieved target patents follow the requirements of the functional reorganization of the system in the trimming method.

(2) Identify the retrieval strategy of the target patent

According to the logic of screening first, classification later, and sorting finally, a multi-level retrieval strategy of target patent based on multi-dimensional retrieval features is formed. First, designers obtain initial inspection patent documents on the patent search platform through functional and functional features, and stores the patent data. Then, the patent text is processed to

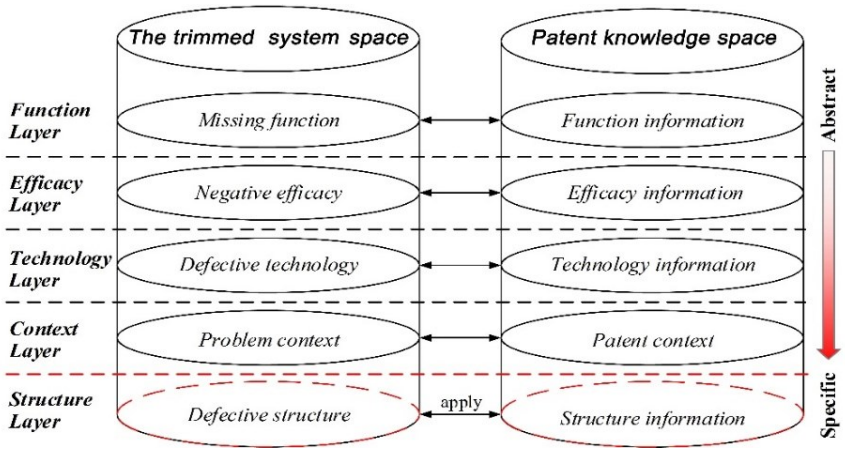

Figure 1. Multi-level features mapping relationship

provide support for patent clustering and sorting. Next, the patent documents are clustered according to the technology feature through the K-means algorithm, and the patent sets of different technical categories are obtained. Finally, the patent documents in the patent set are sorted according to the relevance of context features for designers to choose.

▪3.2 System resource mining based on knowledge in target patents

(1) Identification of target resources based on structural relationships

In order to realize the analogous mapping process of patent knowledge under the condition of complex external attributes, we propose a structural mapping model based on Structural Mapping Theory (SMT). The multi-dimensional mapping between the knowledge modules in the target patent and the problem system is used to obtain and represent the knowledge modules in the target patent that match the problem system.

(2) System resource mining based on attributes and structural relationships of target resource

Combined with the attribute list (Table 1) and attribute evaluation criteria (Table 2), attribute analysis is performed on the target resources and the resources in the system respectively, and the

potential available resources in the system are determined through the attribute similarity calculation.

And then the potential available resource is derived from multiple dimensions such as attributes (geometric attributes, material attributes, etc.), functions, connection relationships, and spatial relationships to achieve useful function redistribution of system from the structural relationship level or the attribute level. Particularly, in order to obtain more smart solutions, the introduction of new resources to complete the reorganization of useful functions of the system is sometimes necessary.

▪3.3 Innovative process model of trimming using patent knowledge to mine system resource

Combining with trimming rules, the innovative process model of trimming using patent knowledge to mine system resource is proposed. The process model includes the following 10 steps, and it is as shown in Figure 2.

(1) Function analysis. Using interaction analysis matrix to construct a functional model.

(2) Determine the components to be trimmed. The components to be trimmed are determined based on harmful functional analysis, cost analysis, root cause analysis, etc.

(3) Discover resources by using trimming rules. Try to solve the problem according to six trimming rules in the traditional trimming method.

(4) Judgement. If the reorganization of useful functions can be completed, go to step 10, otherwise, go to step 5.

(5) Retrieve the target patent. Define the desired function, desired efficacy, context features, and K-value, then input the program to retrieve patents.

(6) Identify target patent. Based on the technology keyword tags, identify the target patent in the relevant target patent sets.

(7) Identify target resources. Construct a partial function model of the trimmed system and the target patent, and identify target resources by mapping.

(8) System resource mining. Identify potential available resources in system by the similarity of attributes. Derive the potential available resources or introduce new resources based on attributes and structural relationships of the target resources.

(9) Judgement. If the reorganization of useful functions of the system is completed, go to step 10, otherwise, go to step 6.

(10) Generate innovative schemes. Improve the design scheme and get domain solution.

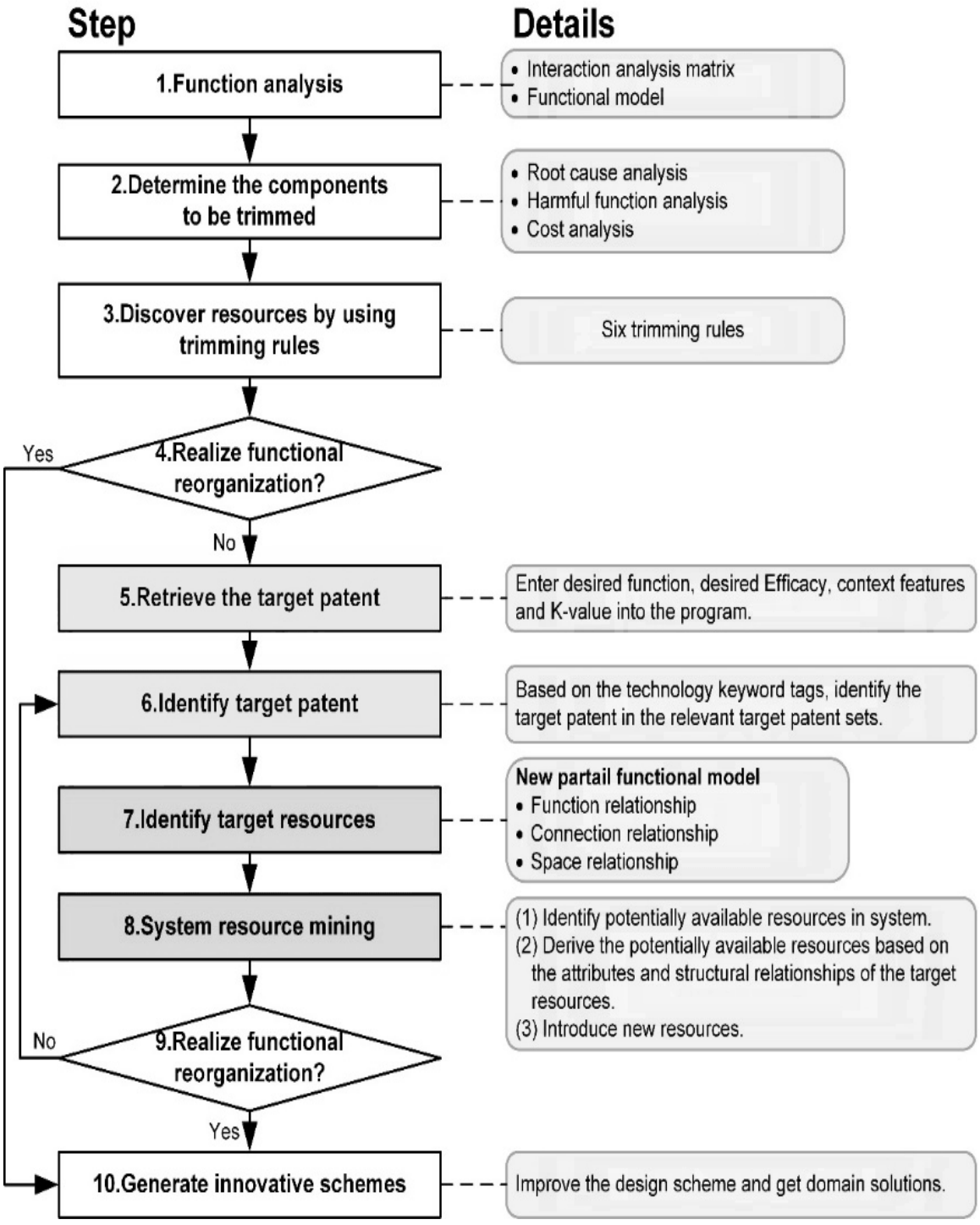

Figure 2. Innovative process model of trimming using patent knowledge to mine system resource

4. Comparative experiment

4.1 Experimental arrangement

The experiment consists of related preparations and two main phases, and the process is as shown in Figure 3. To ensure the accuracy of the experiment, all participants were kept consistent in terms of education, age and profession, and they were randomly and equally divided into five groups. Before the experiment, five supervisors introduced the participants how to fill in the electronic questionnaire and caveats of the experiment, and the participants studied the video explaining the first phase of the experiment. In experiment phase 1, all participants are asked to solve the questions using their own knowledge and experience in 30 minutes. Before the experiment phase 2, the participants study a video explaining the relevant method in advance. After the experiment started, participants in each group used the prescribed method to solve the problem in 90 minutes. The electronic version of the experiment record list can record the time spent by the participants on each answer. After the experiment was completed, the record lists were collected and examined.

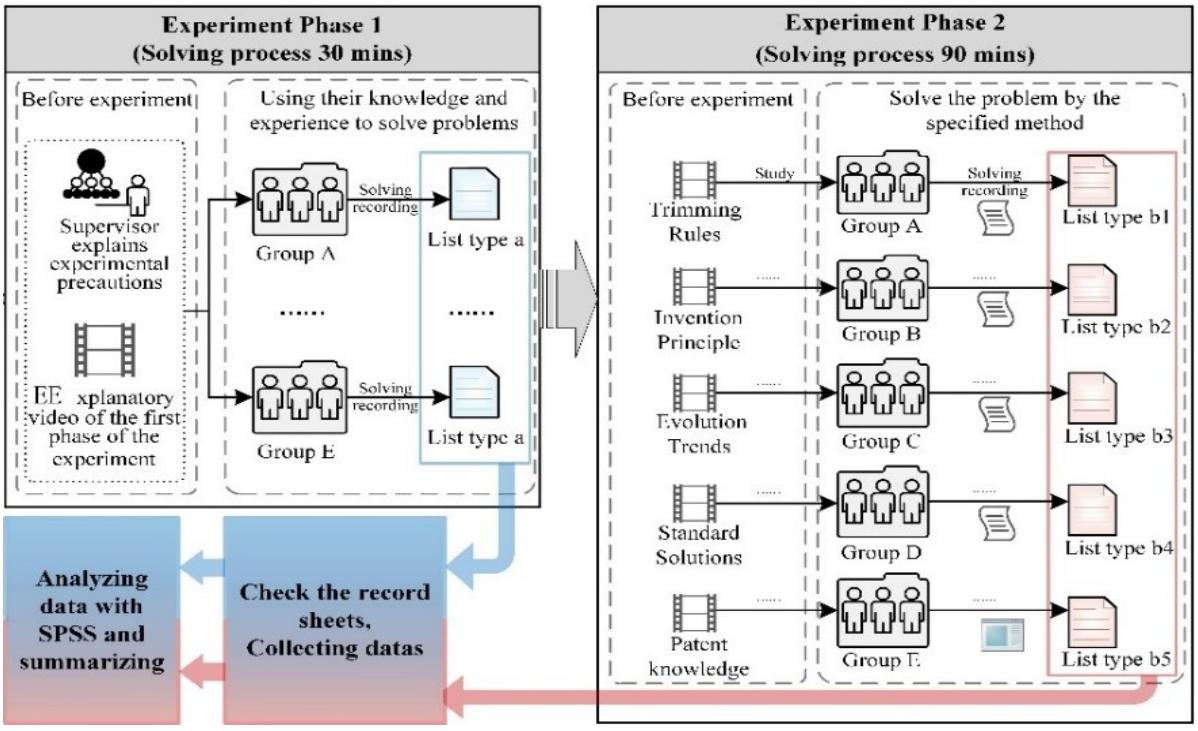

Figure 3. Process of the experiment

4.2 Experimental data analysis

To compare the scheme effects of different methods, the quantity, novelty, and quality of schemes were selected as experimental evaluation criteria. In addition, to compare the use efficiency of each method, three-time indicators were proposed for each scheme generation process: the time taken by participants to find the corresponding design knowledge, the time taken by

participants to obtain the initial design idea, and the time taken by participants to generate the specific design idea. Among the six indicators, the data of three-time indicators are completed by the automatic timing function of the electronic record list, and then the average time spent in each stage is obtained. As in Equation (1).

$$Average\ time_{(Any\ one\ of\ the\ stages)} = \sum_{i=1}^{\text{Quantity}} time_{(\ Any\ one\ of\ the\ stages\ in\ scheme_i)} / Quantity \quad (1)$$

The quantity of schemes is the quantity of specific solution schemes generated during the solving process. Chakrabarti and Khadilkar (2003) considered novelty as the degree of difference of a new solution compared to existing technology solutions. The trimming approach focuses on the reorganization of system functions through the reconfiguration of resources within the system. Therefore, the relevant novelty evaluation criteria are proposed, as shown in Table 3. Quality measures the technical feasibility of the solution and the degree of satisfaction of the design requirements. For the evaluation of quality, the quality evaluation method of Jia, et al. (2019) is cited in this paper, and the evaluation criteria are shown in the Table 4.

Both novelty and quality were scored by five experts according to the corresponding criteria, and Kendall's W coefficients of the scores were calculated to check the evaluation consistency. Based on the definitions and scoring criteria of three metrics of quantity, novelty, and quality, the final solution evaluation metrics were determined as quantity, average novelty, and average quality, and the corresponding calculation formulae are shown in Equation (2).

$$Average\ novelty(quality) = \sum_{i=1}^{Quantity} Novelty(Quality)\ Score\ of\ scheme_i / Quantity \quad (2)$$

Due to the unknown distribution of data and the small sample size, two nonparametric tests, the Kruskal-Wallis and Mann-Whitney test were used to analyze the experimental data to ensure the accuracy of the test results (Rice, 2006).

Table 3. Novelty evaluation criteria

Number	Content	Score
1	working principle is changed	10
2	Structural relationships between components and component features are changed	6
3	Structural relationships between components are changed	3
4	Component features are changed or adjusted	1

Table 4. Quality evaluation criteria (Jia, et al., 2019)

Level	Content	Score
First level	(1) The scheme is not in accordance with the laws of nature	0
	(2) The scheme obeys the laws of nature, but does not solve the target problem	
	(3) The scheme obeys the laws of nature and solves the target problem, but leads to a more serious inability to be consumed	
Second level	(1) The technology does not appear in any field	1
	(2) The technology is already present in other fields, but it is not yet mature and needs to be developed	
	(3) The technology is already available and mature in other fields, but will bring about a significant change in product structure	
Third level	Others	2

4.3 Analysis of experimental results

As shown in Table 5, the significance level of each evaluation criterion was greater than 0.05, which indicates that there was no significant difference in the level of knowledge of participants in each group in terms of quantity of schemes, the average novelty and the average quality.

Table 5. Results of data analysis in experiment phase 1

	Quantity	Average $_{Novelty}$	Average $_{Quality}$
Chi-Square	3.133	5.429	1.451
df	4	4	4
Asymp. Sig. (p)	0.536	0.246	0.835

p>0.05

As shown in Table 6, among the schemes generated in experiment phase 2, the significance levels of all evaluation criteria were less than 0.05, except for the average quality. This indicates that there was no significant difference in the effect of different methods on quality and significant differences in the effect on quantity, novelty, and time spent in each stage of the solving process.

Table 6. Results of data analysis in experiment phase 2

	Quantity	Average Novelty	Average Quality	Time stage1	Time stage2	Time stage3
Chi-Square	15.136	9.760	5.083	14.080	18.080	17.120
df	4	4	4	4	4	4
Asymp. Sig.(p)	0.004	0.045	0.279	0.007	0.001	0.002

The Mann-Whitney test was used to test the independence of other evaluation indexes except for quality, and the results are shown in Table 7, Table 8, and Table 9. And form a box-shaped distribution, as shown in Figure 4.

Table 7. Results of the independence test for the quantity of schemes in phase 2

	Group A	Group B	Group C	Group D	Group E
Group A	—	0.180	0.095	**0.019**	**0.007**
Group B		—	0.439	0.116	**0.012**
Group C			—	0.448	0.065
Group D				—	0.135
Group E					—

Note: data in bold are those with p-values less than 0.05.

Table 8. Results of the independence test for the novelty of schemes in phase 2

	Group A	Group B	Group C	Group D	Group E
Group A	—	0.402	0.402	0.076	**0.009**
Group B		—	0.402	0.465	0.076
Group C			—	0.347	**0.009**
Group D				—	0.076
Group E					—

Note: data in bold are those with p-values less than 0.05.

Table 9. Results of the independence test for the time spent in each stage of the scheme

	Group A	Group B	Group C	Group D	Group E
A	—	0.917/**0.009**/**0.009**	**0.016**/**0.009**/**0.002**	**0.016**/**0.009**/**0.009**	**0.047**/**0.009**/**0.009**
B		—	**0.009**/0.117/**0.009**	**0.009**/**0.016**/0.753	**0.009**/0.117/**0.028**
C			—	0.076/**0.009**/**0.028**	0.347/0.047/**0.009**
D				—	0.117/0.834/**0.047**
E					—

Note: data in bold are those with p-values less than 0.05.

In summary, the advantage of trimming rules is that they can be quickly invoked by designers. After the introduction of the TRIZ tool, the number of solutions, novelty and solution efficiency have been improved to a certain extent. The method proposed in this paper is not significantly different from existing methods in terms of the quality and quantity of generated solutions, time

spent on acquiring knowledge and initial design ideas, but significantly improved in terms of solution novelty and specific solution generation efficiency.

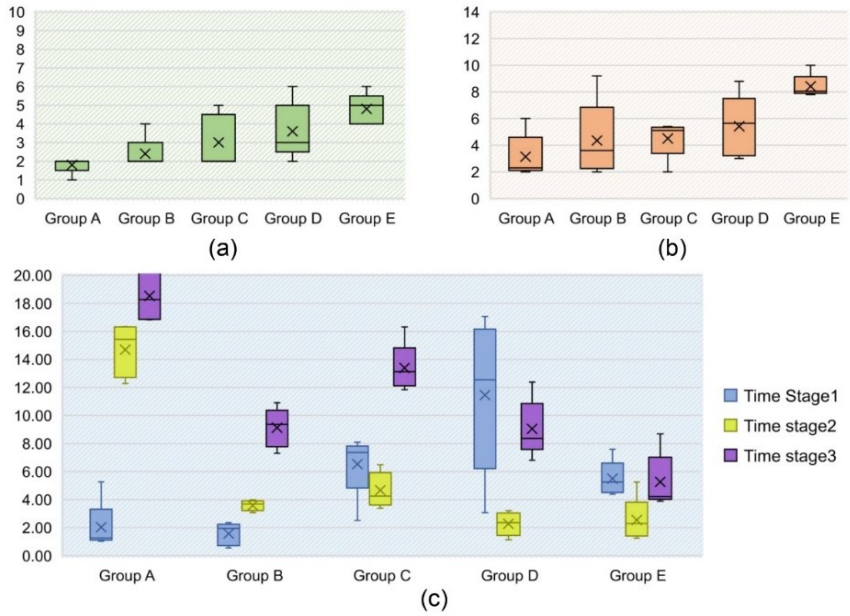

Figure 4. (a) Box distribution for scheme quantity; (b) Box distribution for scheme novelty; (c) Box distribution of the average time spent in each stage

5. Conclusion and Discussion

A trimming-based innovative design method using patent knowledge to assist system resource mining is proposed, which provides a new way to realize the process of reallocation of useful functions in trimming.

In terms of theoretical innovation: (1) According to the logic of screening first, classification later, and sorting finally, a multi-level target patent retrieval strategy based on multi-dimensional retrieval features is formed, which includes the use of function and efficacy features to obtain patents initially. Then, patent documents are clustered according to technical characteristics to obtain patent sets under different technical categories. Finally, the patent sorting in the patent set is achieved through the context features, thus a precise knowledge recommendation method for the trimmed problem system is formed. (2) Based on SMT, a patent knowledge analogy mapping process that can analyze the function, connection, spatial relationships, and attribute characteristics of elements in the patent is formed. This process realizes the analogous mapping of patent knowledge under the condition of complex external attributes from multi-dimensional features, which realizes functional reorganization of the system.

For practical applications: The resulting method is more systematic and more operable. The introduction of patent knowledge effectively breaks the limitations of the designer's own knowledge and reduces the requirements for the designer's own knowledge level. The patent knowledge analogy mapping process based on SMT can effectively break the design fixation and assist the designer to realize fine-grained system resource mining under the condition of complex

external attributes. Due to the cross-domain and specificity of patent knowledge, the efficiency of producing high-quality and specific innovative designs in trimming is improved.

However, there are some limitations in the proposed method. There is still room for further improvement in the accuracy of patent retrieval. Furthermore, the process of system resource mining and attribute analysis requires designers to spend a certain learning cost. In the future, we will further improve and enrich the proposed method. 1) The unsupervised algorithm can be further optimized, and storing the retrieval formula together with the corresponding output results of target patents to achieve fast retrieval of the same or similar problems. 2) Realize the automatic extraction of the structural relationship in the target patent and simplify the process of attribute analysis.

6. Acknowledgements

This paper was sponsored by the National Natural Science Foundation of China (Grant Nos. No.51805142), Natural Science Foundation of Hebei Province (E2017202260) and Scientific Research Program Project of Tianjin Municipal Education Commission (2020KJ056). We thank colleagues and experts for their help and review for the paper improvement.

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整合 UTAUT 模型与网红直播影响消费者选择西塘民宿的意愿调查

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摘　要：

21 世纪，技术改变了人们的生活方式：淘宝改变了人们的购物习惯，微信改变了人们的社交方式，滴滴出行改变了人们的出行方式，而直播改变了人们的沟通方式和生活场景。首先，本文从乡村旅游——以西塘民宿的发展为背景，基于 UTAUT 模型、网红特质对决策信心问题的研究模型。整理出绩效期望、配合情况、专业性、互动性这四大变量，从而构建本文的研究模型。研究发现：消费者特性的绩效期望、配合情况正向显著影响消费者选择西塘民宿的行为意愿；网红直播的互动性正向显著影响消费者选择西塘民宿的行为意愿，专业性正向影响消费者选择西塘民宿的行为意愿；且显著强度依次为：配合情况＞绩效期望＞互动性＞专业性。最后，提出要提高观看网红直播的用户选择西塘民宿的绩效期望，要培训专业网红直播，增加与用户之间的互动，以及多渠道宣传推广西塘民宿这三点建议。

关键词：UTAUT；网红直播；民宿；行为意愿

Abstract:

In the 21st century, technology has changed people's lifestyle: Taobao has changed people's shopping habits, wechat has changed people's social style, Didi Chuxing has changed the way they travel, and live streaming has changed people's communication style and life scenes. First of all, from the background of rural tourism —— to the development of Xitang homestay, based on the UTAUT model, the characteristics of the Internet celebrity on the decision confidence problem research model. Organize out the four variables of performance expectation, cooperation, professionalism and interactivity, so as to build the research model of this paper. Secondly, the data are collected by questionnaire survey, using SPSS statistical software, the reliability validity of the scale is analyzed, and the structural equation model software AMOS is used to test the hypothesis of the research model, the performance expectation and cooperation of consumers significantly affect the behavior willingness of Xitang celebrity live broadcast positively affect the behavior willingness of consumers, and the significant intensity is: cooperation situation> performance expectation> interactivity> professionalism. Finally, it is proposed to improve the performance expectations of users who watch web celebrity live broadcast, train professional web celebrity live broadcast, increase the interaction with users, and promote Xitang B & B through multiple channels.

Key words: UTAUT; Network live red; Home stay; Behavioral Intention

一、引言

（一）研究背景

根据国内旅游抽样调查统计结果，2022 年上半年，国内旅游总人次 14.55 亿，比上年下降 22.2%。国内旅游收入(旅游总消费)1.17 万亿元，比上年下降 28.2%[①]。

艾媒咨询数据显示，2021 年中国在线直播用户规模达到 6.35 亿人，预计 2022 年在线直播用户规模将达到 6.6 亿人[②]。尤其在 2020 年起的疫情背景下，直播带货产业上涨趋势尤其明显。预计 2025 年中国直播人才需求量达 2184.18 万人及企业直播行业企业用户规模将超 270 万家[③]。

现如今，网红直播的模式已经成为大流行趋势，因此我们研究如何促进旅游规模以及网红直播对消费者选择西塘民宿的影响。

（二）研究目的

根据上述研究背景，本研究的目的在于希望整合整合性科技接受与使用模型（UTAUT 模型）、并加入网红直播的特点，了解西塘民宿消费者的行为意愿。主要研究目的为：第一，以整合性科技接受与使用模型（UTAUT 模型）探究网红直播对西塘民宿的行为意愿；第二，加入网红直播的特点，探究网红直播对西塘民宿消费者的行为意愿的影响；第三，利用问卷星收集和分析数据，以此多维度探究消费者的行为意愿，希望对西塘民宿的发展有所帮助。

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③贝思.大文娱行业数据分析：预计 2025 年中国直播人才需求量达 2184.18 万人[EB/OL].
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二、文献综述

本研究针对 UTAUT、网红直播和西塘民宿做相关文献探讨如下：

（一）UTAUT

Venkatesh 等（2003）提出 UTAUT（Unified Theory of Acceptance and Use of Technology)，即整合性科技接受与使用模型[④]。本研究选择 UTAUT 模型为基础研究模型，选取模型中对消费者行为意愿有影响的两个因子，分别是绩效期望和配合情况，探讨它们对于消费者使用行为的影响程度。

1、变量定义

（1）绩效期望(Performance Expectancy, PE)

在 UTAUT 模型中，Venkatesh, Morris（2003）将绩效期望定义为：个体感觉使用技术能够提升工作绩效的程度[⑤]。本文研究的绩效期望是消费者借助各大网络直播平台（例如抖音、小红书等）观看各大网红直播推荐分享的民宿，进而在以后出行旅游时可以做出更多的选择。

（2）配合情况(Facilitating Conditions, FC)

在 UTAUT 模型中，Venkatesh, Morris（2003）将配合情况定义为：个人所感受到组织在相关技术、设备方面对系统使用的支持程度[⑥]。本文研究的配合情况是消费者通过手机等电子设备观看网红直播时，在网红的推荐下产生了想入住民宿酒店的意愿。

3、UTAUT 的研究

（1）国内外对 UTAUT 的研究

国内学者孙丰达（2019）基于 UTAUT 模型的乡村旅游 APP 用户使用意愿影响因素

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④ Venkatesh V, Morris M G, Davis G Bet al. User acceptance of information technology: Toward a unified view[J]. MIS quarterly, 2003, 27(3): 425-478.

⑤Venkatesh V, Morris M G, Davis G Bet al. User acceptance of information technology: Toward a unified view[J]. MIS quarterly, 2003, 27(3): 425-478.

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研究,研究表明，社群影响显著正向影响用户对乡村旅游 APP 的使用意愿；感知风险显著负向影响用户对乡村旅游 APP 的使用意愿[⑦]。

国内学者凌嘉慧（2020）基于 UTAUT 模型的短视频平台信息流广告用户接受度研究,研究表明，社群影响正向影响着用户对短视频平台信息流广告的使用意愿，用户的使用意愿正向影响用户的使用行为[⑧]。

国外学者 Abu Shanab(2007)将移动银行作为研究对象，在 UTAUT 模型的基础上发现努力期望对移动支付行为产生正向影响，绩效期望对移动支付行为产生显著促进作用，社会影响和性别对用户支付行为都产生正向影响[⑨]。

国外学者 Ismaila Ola Ogundega（2021）基于 UTAUT 模型,研究尼日利亚消费者对移动服务的接受度，提出性能预期，相关性，文化，技术支持，信任，安全性和意识已被证明是显著的，因为它们会影响接受调查的尼日利亚消费者对移动支付服务的行为意图[⑩]。

国外学者 Alshammari, Mohammed Habib（2020）调查沙特阿拉伯一所高等教育机构采用学习管理系统 LMS 的教师行为意图时，基于 UTAUT 模型提出行为意图、绩效期望、努力期望、社会规范以及促进条件这五个维度在很大程度上影响教职员工采用 Blackbord LMS 的行为意图[11]。

综合相关文献发现国内学者把 UTAUT 模型用来研究互联网＋和移动服务两大领域展开。

，西方学者把 UTAUT 模型用来研究移动互联网、医疗、教育等领域，但是很少有学者用来研究网红直播影响消费者民宿的选择，本文创新将 UTAUT 模型和西塘民宿相结合，探讨两者的影响因素。

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⑦ 孙丰达.基于 UTAUT 模型的乡村旅游 APP 用户使用意愿影响因素研究[D].2019(01)

⑧ 凌嘉慧.基于 UTAUT 模型的短视频平台信息流广告用户接受度研究[D].2020(01)

⑨Abushanab E,Pearson J M.Internet banking in Jordan: The unified theory of acceptance and use of technology (UTAUT)perspective [J].Journal of Systems &Information Technology,2007,9(1):78-97.

⑩ Ismaila Ola Ogundega.Consumer Acceptance of Mobile Payment Services in Nigeria: A customised Unified Theory of Acceptance & Use Technology (UTAUT) model[D].2021

11 Alshammari, Mohammed Habib.Investigating the Faculty Behavioral Intentions to Adopt Learning Management Systems (LMSs) in a Higher Education Institution in Saudi Arabia[D].2020

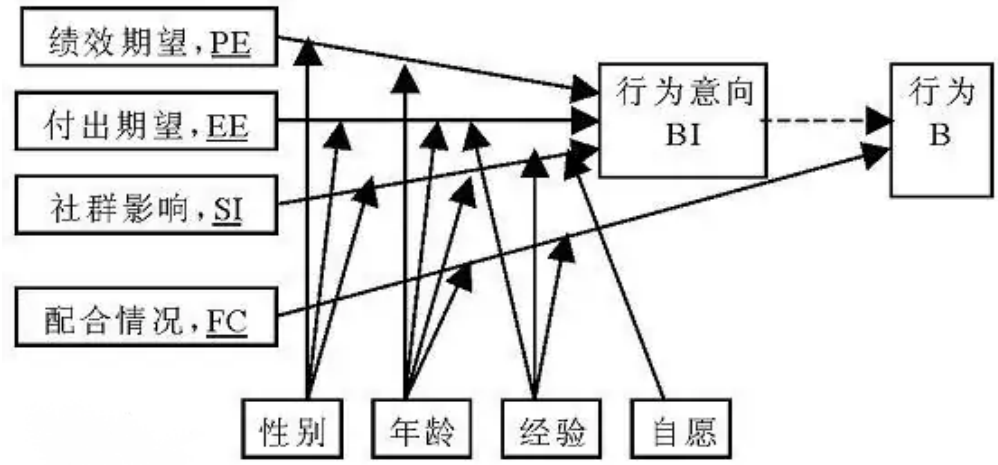

图 1 整合性科技接受与使用模型（UTAUT）

资料来源：Venkatesh，Morris（2003）

（一）网红直播

1、网红直播的定义

“直播带货”从 2009 年开始萌芽起步,2016 年被称为我国网络直播的发展元年。网红直播，即主播在互联网直播平台上使用各种营销手段向消费者展示和介绍产品，受众可以通过弹幕与主播进行互动，激发其购买欲望和促成下单的一种带货模式。在现有的研究中，学者们将其定为“网红直播带货”、“网络直播带货”等。唐绪军等人（2020）在研究 2019-2020 中国新媒体发展现状时，认为电商直播是指主播以视频直播来推荐商品，从而引导消费者购买行为以及最终在平台完成线上交易的一种形式。

2、网红直播的特点

（1）专业性（Professional，简称 P）

李理（2021）认为消费者在发生消费行为决策过程中更加偏向于信任专业领域的人的建议与意见并产生最终的购买行为意愿。这是因为其自身认为与专业人士相比，自己的经验和辨别能力较弱，而专业人士给出的信息可以在一定程度上减少信息不完备性以及信息不对称情况下所产生的购买行为的风险。

本研究认为，如果主播对所推荐的产品有更多的了解和经验和相关的专业知识或者专业技能，就会向观看的消费者分享自己对于该产品的使用经验，便于消费者及时获取有用信息。同时，主播的专业性会让消费者对于产品更加信任，从而提高他们的购买行为意愿。

（2）互动性（Interactivity，简称 I）

德国社会学家 G.齐美尔（1908）所著《社会学》一书中最早使用社会互动一词。廖文虎、尚光辉（2021）认为互动性是主播与消费者之间进行不间断的交互活动，积极和消费者互动了解消费者心理，可以谋求后续收益最佳[12]。互动性作为一种双向交流和沟通方式，可以通过介绍产品信息等方式来影响消费者的购买行为。

本研究认为，互动性能成为网红带货营销新模式中促进消费者产生消费意愿、发生购买行为的关键。直播的互动性能使消费者更有参与感，更加有意愿与主播互动，从而选择主播推荐的产品。

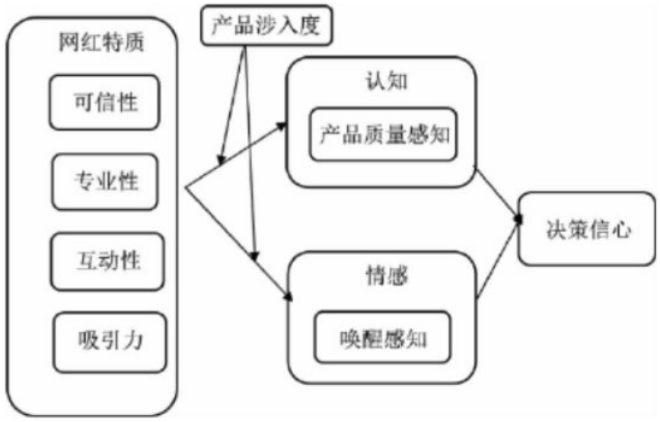

图 2 网红特质对决策信心问题的研究模型

资料来源：廖文虎、尚光辉（2021）

3、网红直播的研究

（1）国内外对网红直播的研究

王迪（2022）研究网红直播带货模式下消费者的购买决策中，研究表明外部刺激因素都能够正向促进消费者购买决策；网红影响力和直播互动性能通过感知价值以及感知

[12] 廖文虎、尚光辉. 网络直播背景下网红对消费者决策信心的影响研究[J]. 河南牧业经济学院学报, 2021(12).

信任间接影响消费者的购买决策[13]。

杨希（2022）在网红直播带货对消费者购买行为影响研究中，研究表明网红的个人魅力、专业程度对消费者的购买行为产生显著正向影响。同时，网红个人魅力、专业性以及环境布置能够通过感知信任对消费者购买行为产生正向影响[14]。

Bell（2003）提出网络直播在远程学习中有着巨大潜力，它是一种授课的机制，是老师和学生之间进行全球互动的方式，也是一种调动学生多元智能来加强学习的方式[15]。

Tong（2017）提出直播是一种新型的网络营销方式，而直播中的交互性和真实性可以影响消费者的信任感，从而增强他们的购买意愿[16]。

综上所述，研究学者都专注于电商直播中网络主播的特征，并探索对消费者购买行为的影响。但由于网红直播带货作为近两年爆火的现象，其相关研究目前相对缺乏。因此，本研究创新把网红直播用来探讨消费者与网红直播之间来选择西塘民宿的影响因素。

（三）民宿的研究

旅游民宿作为一种非标住宿形式的新业态，受到越来越多追求个性化出游体验的旅游者青睐。乡村旅游业能带动乡村产业及乡村经济发展，并为人们提供良好的休闲场所。如今，乡村旅游在多元需求中成长，促进了特色民宿、文化体验、主题研学等项目的开发。那么它就是乡村经济发展的新希望，能最终实现伟大复兴的中国梦[17]。

国内学者诸葛赟凯、周绍健（2017）指出嘉善西塘景区民宿都采取一定的促销，但促销方式大多相似，未形成统一相互促进的产品促销方案，缺乏针对性的产品促销策略。因此，他结合西塘当地民宿发展需要，提出西塘民宿产品促销的相关策略，以此来促进其销售以及推动其及国际健康、持续和稳定的发展。

13 王迪. 网红直播带货模式下消费者的购买决策研究[D]. 2022
14 杨希. 网红直播带货对消费者购买行为影响研究[D]. 2022
15 Bell S.Using Webcasts as a Teaching Tool[J].Tech Trends,2003,47(4):10-14.
16 Bell S.Using Webcasts as a Teaching Tool[J].Tech Trends,2003,47(4):10-14.
17 张芷瑜、郭宇航.“乡村旅游+民宿”可持续发展的现状与对策[EB/OL]. https://h5.drcnet.com.cn/docview.aspx?version=edu&docid=6246213&chnid

国内学者吴云曦、赵斌（2017）通过对嘉善西塘民宿实地调研和国内外民宿发展理论梳理及分析，发现西塘民宿存在缺乏相关法规条例、服务意识较差、缺乏设计等问题，提出政府应该加强管理，加强行业培训，提升服务品质，加大旅游宣传力度等对策和建议。

综合以上文献可以发现，以往对于民宿和网红直播等方面的研究还没有给予足够的重视。本文创新将 UTAUT 模型和网红直播相结合探讨影响消费者对西塘民宿的选择意愿。

三、研究假设及模型构建

（一）模型构建

本研究以 Venkatesh，Morris 等学者所提出的 UTAUT 为基础模型，在该原始模型中，已包含 UTAUT 消费者特性对行为意愿之影响力的探讨。本研究将重复验证 UTAUT 在观看网红直播的用户为研究对象，其研究假设是否仍然成立。同时将网红直播概念化为专业性、和互动性，综上所述，本研究模型如图 3 所示：

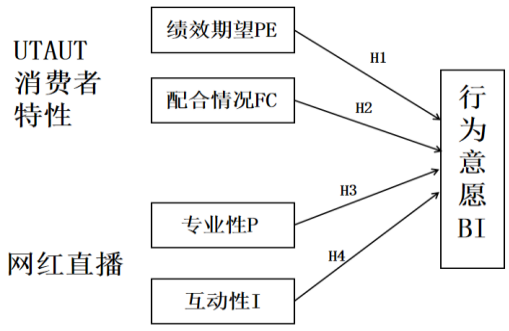

图 3 本研究之研究架构图

（二）研究假设

（1）绩效期望及行为意愿

消费者特性的绩效期望会影响西塘民宿消费者的行为意愿：本文研究的绩效期望是消费者借助各大网络直播平台（例如抖音、小红书等）观看各大网红直播推荐分享的民宿，进而在以后出行旅游时可以做出更多的选择。国内外研究学者在进行理论研究的时候都用到了 UTAUT 模型理论框架中的绩效期望，并且将绩效期望与消费者意愿相联系。原林（2019）在研究共享单车用户使用行为的影响因素时，得出绩效期望会对使用意愿产生正

向影响[18]。 王晓慧（2021）以武汉市青少年为研究对象，基于 UTAUT 模型发现绩效期望正向影响青少年持续参加体育培训意愿[19]。

基于以上的研究，当绩效期望越高，选择民宿的难度越大，所以网红直播推荐的产品是否符合消费者的期望是很重要的，他们会产生对网红民宿选择的意愿并且愿意付出金钱和精力。本文提出以下假设：

H1：消费者特性的绩效期望会对西塘民宿消费者的行为意愿产生正向影响。

（2）配合情况及行为意愿

消费者特性的配合情况会影响西塘民宿消费者的行为意愿：本文研究的配合情况是消费者通过手机等电子设备观看网红直播时，在网红的推荐下产生了想入住民宿酒店的意愿。梁太鑫、刘世峰（2022）在基于 UTAUT 模型的旅游信息服务平台用户使用意愿研究中，得出配合情况对使用意愿有显著的正向影响[20]。张军翔、张涵等人(2022)以大学生为研究对象，在基于 UTAUT 模型的在线学习行为及其影响因素的研究中，得出配合情况对学习者行为意愿有正向影响[21]。

基于以上的研究，我们希望可以通过配合情况促进消费者对西塘民宿的消费。本文提出以下假设：

H2：消费者特性的配合情况会对西塘民宿消费者的行为意愿产生正向影响。

（3）专业性及行为意愿

网红直播的专业性会影响西塘民宿消费者的行为意愿：本文研究的专业性是消费者在

18 原林. 基于 UTAUT 模型共享单车用户使用行为的影响因素研究[D]. 2020（01）:22－23
19 王晓慧.基于 UTAUT 模型的青少年持续参与体育培训影响因素研究——基于武汉市青少年的调查[D].2021(04):20
20 梁太鑫,刘世峰.基于 UTAUT 模型的旅游信息服务平台用户使用意愿研究[J].情报科学,2022,40(02).
21 张军翔、张涵、朱宇、陈雪;、徐琦.基于 UTAUT 模型的大学生在线学习行为及其影响因素研究[J].湖北师范大学学报(自然科学版),2022,42(2).

观看网红直播时，认为直播网红具有专业知识和技能且有过入住该西塘民宿的真实经历。国内学者李臻（2019）在研究网红特征对消费者购买行为的影响时，认为网红的专业性会对消费者的行为产生影响[22]。李理（2021）在研究网红直播带货对消费者购买意愿的影响研究中，得出网红主播专业性显著正向影响影响消费者的购买意愿[23]。

基于以上的研究，如果主播是销售商品领域的专家，消费者往往相信他们的推荐，让消费者更加愿意选择主播推荐的民宿酒店并且会毫不犹豫地进行下单消费。本文提出以下假设：

H3：网红直播的专业性会对西塘民宿消费者的行为意愿产生正向影响。

（4）互动性及行为意愿

网红直播的互动性会影响西塘民宿消费者的行为意愿：本文研究的互动性是网红借助直播平台与消费者进行互动，打破了传统营销模式下单向营销的限制，具有很强的实时性、动态性以及双向互动性，更能唤起消费者的参与欲望。根据马斯洛需求层次理论，互动性行为满足了消费者更高层次的社交、尊重和自我实现需求，更加迎合消费者的情感诉求。但鸣啸、武峰（2018）在研究网络直播营销对购买意愿的影响实证研究中，得出互动性对消费者购买意愿有积极影响[24]。廖文虎、尚光辉（2021）在研究网络直播背景下网红对消费者决策信心的影响中，得出网红专业性显著正向影响购买意向和行为[25]。

基于以上的研究，互动性能成为网红带货营销新模式中促进消费者产生消费意愿、发生购买行为的关键变量。直播的互动性能使消费者更有参与感，更加有意愿与主播互动，从而选择主播推荐的产品。本文提出以下假设：

22李臻.网红特征对消费者购买行为的影响研究[D]. 北京邮电大学, 2021(03):57-58.
23 李理. 网红直播带货对消费者购买意愿影响机制研究[D]. 哈尔滨工业大学，2021（06）:59-60
24 但鸣啸, 武峰. 网络直播营销对购买意愿的影响实证研究[J]. 管理观察，2018, (36).
25 廖文虎、尚光辉. 网络直播背景下网红对消费者决策信心的影响研究[J]. 河南牧业经济学院学报, 2021(12).

H4：网红直播的互动性会对西塘民宿消费者的行为意愿产生正向影响。

表 1 研究假设汇整表

H1	消费者特性的绩效期望会对西塘民宿消费者的行为意愿产生正向影响。
H2	消费者特性的配合情况会对西塘民宿消费者的行为意愿产生正向影响。
H3	网红直播的专业性会对西塘民宿消费者的行为意愿产生正向影响。
H4	网红直播的互动性会对西塘民宿消费者的行为意愿产生正向影响。

四、调查设计

（一）量表设计

本文在对国内外学者的研究成果和文献整理的指出上，对消费者特性、网红直播、行为意愿等因素尽享了分析。以下的表格显示了研究的变量。

最后的量表是在查阅了大量国内外的学术研究量表后才得以形成，以保证量表的科学性和精确度。本文研究的问卷调查使用的是李克特量表：用来衡量顾客态度和意见的评分量表。受访者会被要求按照从“非常不同意”、“不同意”、“一般”、“同意”、“非常同意”来表明他们同意或不同意某项陈述的程度（这一问题可以用来衡量客人的满意度、频率、重要性或可能性等问题类型）

表 2 整合UTAUT模型与网红直播影响消费者选择西塘民宿的意愿调查问卷设计

编号	变量	测量量表	指标来源
1	绩效期望	1. 该主播推荐西塘民宿的有用信息比我期望了解的更多	Venkatesh, Morris（2003） 原林（2020） 王晓慧（2021）
2		2. 该主播给我提供了更多西塘民宿的选择	
3		3. 该主播可以帮助我更高效地选择西塘民宿并制定后续的旅行计划	
4		4. 该西塘民宿入住后所提供的服务要比我期望的更好	
5		5. 该西塘民宿的服务给我带来的益处大于我的心理预期	
6		6. 整体来说，我对该西塘民宿的期望在体验过程中得到了满足感，并且为我提供了个性化出游的需求	
7	配合情况	1. 当地政府对于西塘民宿的宣传推广使得让我想要去入住	梁太鑫、刘世峰（2022） 张军翔、张涵等人(2022)
8		2. 我认为直播平台的推荐更让我想要去西塘民宿入住	
9		3. 我的手机等电子设备支持我观看该直播（如:使用5g，WiFi观看时更流畅）	
10		4. 我的手机等电子设备可以连接到网络并支持我观看该直播不会卡顿	
11	行为意愿	1. 主播推荐有关的西塘民宿对我的行为决策给予了帮助	T. H. Daveport等(1997) Hong&Cha（2013） 杨刚等(2018)
12		2. 主播推荐有关西塘民宿的信息改变了我对它的原有看法	
13		3. 观看网红直播影响了我对该西塘民宿的购买意愿	
14		4. 我想要去该西塘民宿入住	
15		5. 我担心直播平台会泄漏我的居住地点等个人信息	
16		6. 我担心该西塘民宿所提供的产品或服务与入住后的实际情况不符合	
17		7. 我会强力推荐别人去该西塘民宿入住	
18	专业性	1. 我认为主播具有相关西塘民宿的知识	Gily(1998) 李臻（2019） 廖文虎、尚光辉（2021）
19		2. 我认为主播具有专业的技巧	
20		3. 我认为主播对该西塘民宿的分析有理有据且有一定的实际效果	
21		4. 我认为主播对该西塘民宿的信息的了解程度很全面	
22		5. 此主播有过入住该西塘民宿的真实经历	
23	互动性	1. 主播有注意到我的问题并进行交流互动，增强了我对其产品的了解	但鸣啸、武峰（2018） 李理（2021）
24		2. 主播与我的互动拉近了相互间的距离	
25		3. 我所观看的直播内容能让我有效的参与进去	

（二）问卷调研

本文的研究对象为观看网红直播的消费者。因为网络问卷不受时间和地点的限制，具有便捷和高效的特点，所以本文采用网络问卷的形式发放。本人于 2022 年 8 月 7 日到 9 月 7 日间使用问卷星官网设置好问卷，并通过 QQ、微信等社交软件发放问卷。

本次调研共回收 315 份调研问卷，其中有效问卷 242 份，有效回收率为 76.83%。

五、资料分析

（一）样本结构叙述性分析

1.样本分布情况

本研究 242 份问卷填写者的基本资料分析如表 3 所示。男性有 111 人（46.091%）、女性有 131 人(53.909%)；年龄小于 18 岁的有 16 人(6.612%)、18-25 岁的有 85 人(35.124%)、26-35 岁的有 101 人（41.736%）、36 岁及以上的有 40 人（16.529%）；学历在初中及以下学历的有 23 人（9.465%）、高中或中专学历的有 35 人（14.403%）、大专或本科学历的有 121 人(49.794%)、本科以上的有 64 人(26.337%)；职业为公司职员的有 77 人(31.818%)、企业主管的有 38 人(15.702%)、教师的有 35 人(14.463%)、学生的有 29 人(11.983%)、公务员的有 28 人（11.570%）、军人/警察的有 19 人（7.851%）、自由职业者的有 8 人（3.306%）、其他职业的有 5 人（2.066%）、退休人员的有 3 人（1.240%)。

表 3 样本特征统计一

题项	选项	样本数	百分比
性别	男	111	45.868%
	女	131	54.132%
年龄	18 岁以下	16	6.612%
	18-25 岁	85	35.124%
	26-35 岁	101	41.736%
	36 岁及以上	40	16.529%
学历	初中及以下	23	9.504%

题项	选项	样本数	百分比
	高中或中专	35	14.463%
	大专或本科	120	49.587%
	本科以上	64	26.446%
职业	公司职员	77	31.818%
	企业主管	38	15.702%
	教师	35	14.463%
	学生	30	11.983%
	公务员	28	11.570%
	军人/警察	19	7.851%
	自由职业者	8	3.306%
	其他	5	2.066%
	退休人员	3	1.240%

（二）信度与效度分析

1.信度分析

信度主要是指测量结果的稳定性、可靠性、一致性，也就是研究样本是否如实的回答了问题，可以用于判断数据的真实性。在信度的检验上，常用 Cronbanch α 系数的大小来衡量，当该系数越接近于+1 时，量表的信度越高。DeVeill（1991）认为信度检验值在 0.7 以上为可接受值[26]。一般 Cronbach's α 系数如果在 0.9 以上，则该测验或量表的信度甚佳，0.8-0.9 之间表示信度不错，0.7-0.8 之间则表示信度可以接受，0.6-0.7 之间表示信度一般，0.5-0.6 之间表示信度不太理想，如果在 0.5 以下就要考虑重新编排问卷。本研究的量表信度分析结果如表 5 所示：

表 5 信度分析表

维度	问项代码	项目 Cronbach Alpha	Cronbach Alpha	基于标准化项目的 Cronbach Alpha	Cronbach Alpha	基于标准化项目的 Cronbach Alpha
绩效期望	Q1_1	0.899	0.922	0.922	0.950	0.950
	Q1_2	0.909				

[26] DeVellis, R. F. Scale Development Theory and Applications[M]. London: SAGE, 1991.

	Q1_3	0.910				
	Q1_4	0.911				
	Q1_5	0.911				
	Q1_6	0.907				
配合情况	Q2_1	0.833	0.863	0.864		
	Q2_2	0.827				
	Q2_3	0.834				
	Q2_4	0.810				
行为意愿	Q4_1	0.907	0.928	0.929		
	Q4_2	0.918				
	Q4_3	0.917				
	Q4_4	0.920				
	Q4_5	0.919				
	Q4_6	0.918				
	Q4_7	0.919				
专业性	Q5_1	0.876	0.896	0.897		
	Q5_2	0.871				
	Q5_3	0.868				
	Q5_4	0.880				
	Q5_5	0.875				
互动性	Q6_1	0.775	0.851	0.852		
	Q6_2	0.801				
	Q6_3	0.799				

从上表可知，本研究量表的各项的α系数在0.851-0.928，每个变量的α系数均在0.77以上，量表整体达到了0.950，说明本研究量表信度水平高，可用于进一步分析。

2. 效度分析

效度分析简而言之就是测量结果的有效性。1981 年 Fornell & Larcker 认为若同时满足下列三项指标则判定测量模型具有收敛效度：问项的因素负荷量必须超过 0.7 且于 P 检验时显著；潜在变量组合信度 CR 值必须大于 0.6，数值越高那么就意味着维度具有越高的内部一致性；每个维度的平均变异萃取量必须大于 0.5[27]。

[27] Hair J F,Anderson R E,Tatham R L,et al.Multivariate data analysis[M].Upper Saddle River,NJ:Prentice

本研究的收敛效度分析结果如表 6 所示：

表 6 收敛效度分析表

维度	问项代码	标准化因素负荷量	P	SMC	C.R.	AVE
绩效期望	Q1_1	0.893		0.797	0.922	0.665
	Q1_2	0.804	***	0.646		
	Q1_3	0.796	***	0.634		
	Q1_4	0.789	***	0.623		
	Q1_5	0.778	***	0.605		
	Q1_6	0.828	***	0.686		
配合情况	Q2_1	0.845		0.714	0.864	0.614
	Q2_2	0.747	***	0.558		
	Q2_3	0.774	***	0.599		
	Q2_4	0.765	***	0.585		
行为意愿	Q4_1	0.892		0.796	0.908	0.586
	Q4_2	0.753	***	0.567		
	Q4_3	0.744	***	0.554		
	Q4_4	0.727	***	0.529		
	Q4_5	0.736	***	0.542		
	Q4_6	0.742	***	0.551		
	Q4_7	0.753	***	0.567		
专业性	Q5_1	0.788		0.621	0.897	0.635
	Q5_2	0.810	***	0.656		
	Q5_3	0.826	***	0.682		
	Q5_4	0.766	***	0.587		
	Q5_5	0.793	***	0.629		
互动性	Q6_1	0.796		0.634	0.852	0.657
	Q6_2	0.791	***	0.626		
	Q6_3	0.844	***	0.712		

从表 6 可知，本研究量表所有问项的因素负荷量皆大于 0.7 且显著；潜在变量组合信度 CR 值介于 0.852-0.922 之间；各个维度的平均变异萃取量介于 0.586-0.665 之间。同时满足了以上三项指标的理想值，这表示同一潜在维度的所有测量问项彼此之间的相关值很高，也就是说本研究测量模型具有收敛效度。

Hall, 1998.

然而，除了分析收敛效度还需要分析区分效度。1998 年 Hair 等人建议潜在维度的平均变异萃取量的平方根值应大于特定潜在维度与其他维度之间的相关系数，则维度间具有区分效度[28]。本研究的区分效度分析结果如表 7 所示。

表 7 区分效度分析表

	互动性	专业性	配合情况	绩效期望	行为意愿
互动性	**0.811**				
专业性	0.000	**0.797**			
配合情况	0.000	0.000	**0.784**		
绩效期望	0.000	0.000	0.000	**0.815**	
行为意愿	0.174	0.143	0.279	0.200	**0.766**

注：对角线上的数值（粗字体）代表平均变异萃取量的平方根，非对角线上的数值则为各构面间的相关系数。

本研究潜在维度的平均变异萃取量的平方根值最小数值为 0.766，除满意度与持续使用意愿的相关系数外均高于其他两两维度之间的相关系数，这说明本研究各潜在维度之间具有良好的区分效度。

（三）结构模型分析

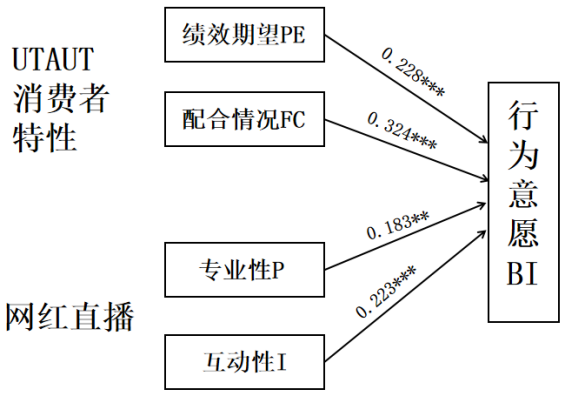

图 4 模型标准化路径系数图

28 Hair J F, Anderson R E, Tatham R L, et al. Multivariate data analysis[M]. Upper Saddle River, NJ: Prentice Hall, 1998.

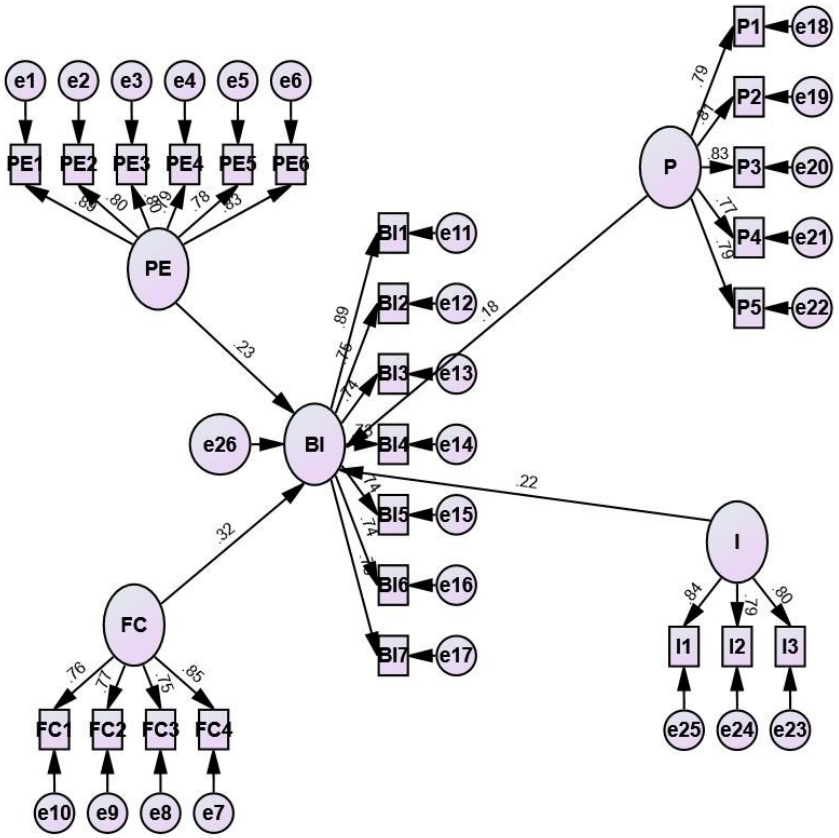

图 5 本研究模型路径

1.路径检验

路径检验是为得到研究模型中各个变量间的相关关系，并验证这些系数的显著性概率。本文使用 AMOS 软件，结合本研究模型，对各变量进行路径检验，检验结果如表 7 所示。

表 3 结构模型路径检验表

路径	路径系数	标准误差	T 值	P 值
绩效期望→行为意愿	0.228	0.060	3.603	***
配合情况→行为意愿	0.324	0.064	4.856	***
专业性→行为意愿	0.183	0.068	2.834	**
互动性→行为意愿	0.223	0.070	3.344	***

注：***P＜0.001，**P＜0.01，*P＜0.05

专业性对行为意愿的路径不够显著，其他路径均达到显著性水平，结构模型路径分析系数为：（1）绩效期望对行为意愿的路径系数为 0.228。（2）配合情况对行为意愿的路径系数为 0.324。（3）专业性对行为意愿的路径系数为 0.183。（4）互动性对行为意愿的路径系数为 0.223。

3. 实证结果及分析

通过上述路径分析图可判断出本研究模型所提出的研究假设成立情况，结果如下表 8 所示。

表 4 研究假设检验结果

编号	假设	检验结果
H1	消费者特性的绩效期望会对西塘民宿消费者的行为意愿产生正向影响。	成立
H2	消费者特性的配合情况会对西塘民宿消费者的行为意愿产生正向影响。	成立
H3	网红直播的专业性会对西塘民宿消费者的行为意愿产生正向影响。	成立
H4	网红直播的互动性会对西塘民宿消费者的行为意愿产生正向影响。	成立

（1）消费者特性的绩效期望、配合情况对西塘民宿消费者的行为意愿产生正向影响。

根据上文的研究结果，西塘民宿消费者的行为意愿受到消费者特性的绩效期望、配合情况两个维度的显著正向影响，假设 1、假设 2 均得到支持。绩效期望对行为意愿的正向影响与原林等学者的研究结论相符。配合情况对行为意愿的正向影响与梁太鑫等学者的研究结论相符。

绩效期望（r=0.228,p<0.001)对西塘民宿消费者的行为意愿产生正向影响,假设 1 得到支持。这一结果说明了，消费者所得比预期更高的时候，进而间接提高西塘民宿消费者的行为意愿。

配合情况（r=0.324,p<0.001)对西塘民宿消费者的行为意愿产生正向影响。这一结果说明了，消费者感受到相关技术、电子设备对系统使用支持的时候，进而间接提高西塘民宿消费者的行为意愿。

（2）网红直播的专业性、互动性对西塘民宿消费者的行为意愿产生正向影响。

根据上文的研究结果，西塘民宿消费者的行为意愿受到网红直播的专业性、互动性两个维度的显著正向影响，假设 3、假设 4 均得到支持。专业性对行为意愿的正向影响与李臻等学者的研究结论相符。互动性对行为意愿的正向影响与但鸣啸等学者的研究结论相符。

专业性（r=0.183,p<0.01)对西塘民宿消费者的行为意愿产生正向影响。这一结果说明了，具有较高专业能力的网红直播的推荐更容易被消费者所信任和采纳意见，专业能力可以对购买决策产生至关重要的影响，进而提高西塘民宿消费者的行为意愿。

互动性（r=0.223,p<0.001)对西塘民宿消费者的行为意愿产生正向影响。这一结结果说明，与用户及时进行交流互动的网红直播会增强消费者对产品的了解且拉近了彼此间的距离，有效互动对购买决策产生重要影响，进而提高西塘民宿消费者的行为意愿。

六、研究建议

基于上述研究结果，本研究为网红直播行业如何提高观看网红直播的用户选择西塘民宿的行为意愿，提出以下几条建议：

1、提高观看网红直播的用户选择西塘民宿的绩效期望

本研究结果显示，绩效期望到行为意愿的路径回归系数为 0.229，说明对西塘民宿消费者的行为意愿有显著正向影响。因此，消费者得到的相关有用信息更多，所带来的益处大于心理预期，更高效选择并指定后续旅行计划时，进而影响观看网红直播选择西塘民宿的用户的购买意愿。

所以，网红直播在直播过程中要提供详细且真实的产品信息，提供多种选择给予消费者。只有服务益处大于心理预期，在体验过程中得到满足感，满足消费者的需求，他们才会产生对网红民宿选择的意愿，并且愿意做购买决策。

2、培训专业网红直播，增加与用户之间的互动

本研究结果显示，专业性到行为意愿的路径回归系数为 0.182，结果并不显著，说明用户在观看网红直播的时候认为网红直播的专业能力还不够强。互动性到行为意愿的路径回归系数为 0.223，说明与用户及时进行交流互动的网红直播会增强其对产品的了解且拉近了彼此的距离，有效互动对购买决策产生重要影响，进而提高西塘民宿消费者的行为意愿。

所以，要培训主播在所推荐产品的领域中的专业性。当专业能力不断提高的时候，给消费者所带来的价值才会更高，那么消费者在做出最终购买决策时会更加信任拥有专业能力的网红直播。此外，网红直播的团队以及商家都要重视消费者的利益。网红直播要用心维护好自己的粉丝社群，对粉丝提出的产品相关问题要及时进行反馈互动，粉丝才会出于对网红主播的喜爱和信任选择相信主播的推荐并最终购买产品。因此，网红直播也要坚持为自己所推荐的产品最好相关背书，这样会有助于在直播的过程中提高高转化率。

3、多渠道宣传推广西塘民宿

针对用户认识现状，对于西塘主题的民宿主要是通过电视、网络等媒体播出宣传视频，借助 OTA 平台宣传民宿信息、特色介绍以及当地政府对于西塘民宿的宣传推广，有利于开拓民宿市场，引导消费者选择购买入住。

另外，经营者应该设计有创意的广告标语，还要树立“服务即营销、营销即服务”的思想，在营销工作做得出色的同时，要保持优质的服务水平，才能让经营的民宿有更长远的发展。

七、展望与不足

本研究模型适配度不是很理想,由于调查问卷的对象是任何人，而不是特定的某类群体，导致模型适配度不高；同时，收集问卷样本的数量不是很多，只回收了 315 份调研问卷，其中有效问卷 242 份，有效回收率只达到 76.83%。假如有机会，还会继续完善问卷和收集更多的问卷数量。

附件（一）问卷设计

尊敬的女士/先生：

您好！这是一份关于网红直播能够影响消费者选择西塘民宿的意愿调查，本研究的内容主要在于探讨直播中网红的哪些因素会影响消费者对西塘民宿的选择。本研究调查采取匿名方式，您所填写的资料将仅供学术分析研究使用，不作个别披露或其他用途，请放心作答。

以下有关您的个人资料，仅供学术统计分析之用。绝对保密，敬请放心作答。

1.您的性别

2.您的年龄

3.您所从事的职业

4.您的学历

5.您的平均月消费水平（人民币）

6.您是否有看直播的经历

7.您在哪些平台观看过直播

8.您有没有入住西塘民宿的意愿

9.如果您有入住西塘民宿的意愿，您是否会选择在直播平台预定

10.该主播推荐西塘民宿的有用信息比我期望了解的更多？

11.该主播给我提供了更多西塘民宿的选择？

12.该主播可以帮助我更高效地选择西塘民宿并制定后续的旅行计划？

13.该西塘民宿入住后所提供的服务要比我期望的更好？

14.该西塘民宿的服务给我带来的益处大于我的心理预期？

15.整体来说，我对该西塘民宿的期望在体验过程中得到了满足感，并且为我提供了个性化

出游的需求？

16.当地政府对于西塘民宿的宣传推广使得让我想要去入住？

17.我认为直播平台的推荐更让我想要去西塘民宿入住？

18.我的手机等电子设备支持我观看该直播（如:使用 5g，WiFi 观看时更流畅）？

19.我的手机等电子设备可以连接到网络并支持我观看该直播不会卡顿？

20.主播推荐有关的西塘民宿对我的行为决策给予了帮助？

21.主播推荐有关西塘民宿的信息改变了我对它的原有看法？

22.观看网红直播影响了我对该西塘民宿的购买意愿？

23.我想要去该西塘民宿入住？

24.我担心直播平台会泄漏我的居住地点等个人信息？

25.我担心该西塘民宿所提供的产品或服务与入住后的实际情况不符合？

26.我会强力推荐别人去该西塘民宿入住？

27.我认为主播具有相关西塘民宿的知识？

28.我认为主播具有专业的技巧？

29.我认为主播对该西塘民宿的分析有理有据且有一定的实际效果？

30.我认为主播对该西塘民宿的信息的了解程度很全面？

31.此主播有过入住该西塘民宿的真实经历？

32.主播有注意到我的问题并进行交流互动，增强了我对西塘民宿的了解？

33.主播与我的互动拉近了相互间的距离？

34.我所观看的直播内容能让我有效的参与进去？

Prioritized TRIZ Effect Solution Identification Using Support Vector Machine

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Abstract

The traditional TRIZ problem solving depends on logical reasoning, expert experience and professional knowledge to determine the solution design of the problem. In this way, relying solely on human logical thinking and expert experience to produce a solution model has the shortcomings of strong subjectivity and low repeatability and verification. At the same time, in terms of problem-solving tools, such as Oxford Creativity (2017), Goldfire Innovator (2017), CREAX (2011), etc., there are more than 900 kinds of effects that have been sorted out. It is time-consuming and subjective to perform manual screening one after another. If there is not an objective prioritization when several solution models are selected. As a result, in TRIZ, the attributes and functions of fuzzy logic concepts are used together as the characteristic attributes and functions of the problem, and the problem-solving process of the effect database is used. The multivariate calculation method of 「Three-dimensional fuzzy thinking」 replaces the thinking mode of binary logic and automatically searches for suitable effect solutions through Support Vector Machine(SVM) in the AI algorithm and according to their calculated scores through SVM, the feasible priority is arranged to form an AI+TRIZ problem-solving mode, which enables the problem solver to quickly obtain reliable and objective problem-solving answers through an effective and reliable problem-solving platform, and then use the problem-solving answers for target patent enhancement, Regeneration, get invention opportunities.

Therefore, the overall contributions of this research: 1) Establish a mature effect case database system, store data in a simple and systematic mode, and facilitate sorting or application to algorithm software; and collect as many cases as possible to add to the database to improve The stability and success rate of this research method. 2) Establish a mathematical model as a Classification Engine (CE) to identify research opportunities for solutions, and can be applied to various TRIZ problem-solving tools such as effects, standard solutions, and invention principles. 3) SVM training case data, test case database for unsolved problems, provide problem solving models available to problem solvers, including reference effects, and sort the answering priority according to the support vector machine classification results.

Keyword: TRIZ, Effect, AI, Support Vector Machine

I. Research background and motivation

Effect Database is an effective tool to help improve the system in TRIZ, the concept is to use the current engineering system needs "Function" and the desired change or maintain attribute as a keyword, to the effect database to search for the corresponding effect information, and then according to the problem to associate a specific solution. (Sheu, D. Daniel, 2015).

At present, the commonly used effects database, such as CREAX (2011), Goldfire Innovator (2017), Oxford Creativity (2017), etc., have been sorted out of more than 900 effects, but to manually screen one by one, it is quite time-consuming and subjective, and if there are several solution models, there is no objective priority when choosing.

The traditional TRIZ solution method relies on logical reasoning, expert experience and professional knowledge to determine the solution design, so that the solution model that relies solely on artificial logical thinking and expert experience output has strong subjectivity and low repeatability and verification. In addition, for the use of attributes and functions in the process of problem solving, imported into the mathematical and physical solution method, the quantitative and "three-element fuzzy thinking" mode of the plurality calculation method will replace the dualistic logic thinking mode, and then obtain a more effective problem solving effect.

Therefore, the algorithm that imports artificial intelligence (AI) can take the attributes and functions with fuzzy logic concepts together as the characteristics of the problem, automatically search out the suitable effect through the algorithm, and prioritize according to the feasibility, forming an AI+TRIZ problem solving mode, which allows the problem solver to quickly get a reliable and objective solution through an effective and reliable problem solving platform, and then can use the problem solving platform for target patent enhancement and regeneration. Get the opportunity to innovate.

II. Research architecture

The specific research architecture can be divided into three parts: effect case data attribute and functional analysis, the effect solution software module development and target patent regeneration, the detailed steps are the first step is to collect case data from the way to collect the innovative cases that have been solved, as well as the application cases of each effect in the effect knowledge base, as the information required for the classification of support vector machines and follow-up training and testing data.

The second step is to parse the attributes/functions/effects within the case database into an array of case problem characteristics and solutions with "attribute analysis", "function. analysis" and "effect solutions" to ensure that the user information is correct and complete, and the solution array table can be importe0d into subsequent AI algorithms to automatically process the data.

The third step is to introduce the solution array table into the SVM algorithm for training and testing, and develop software that can assist in the implementation of effective identification and prioritization effect solutions. The detailed research process is shown in Figure 1.1 with the use of

TRIZ effect solution research process and Figure 1.2.1, 1.2.2 and 1.2.3 SVM software module development process for the effect solutions.

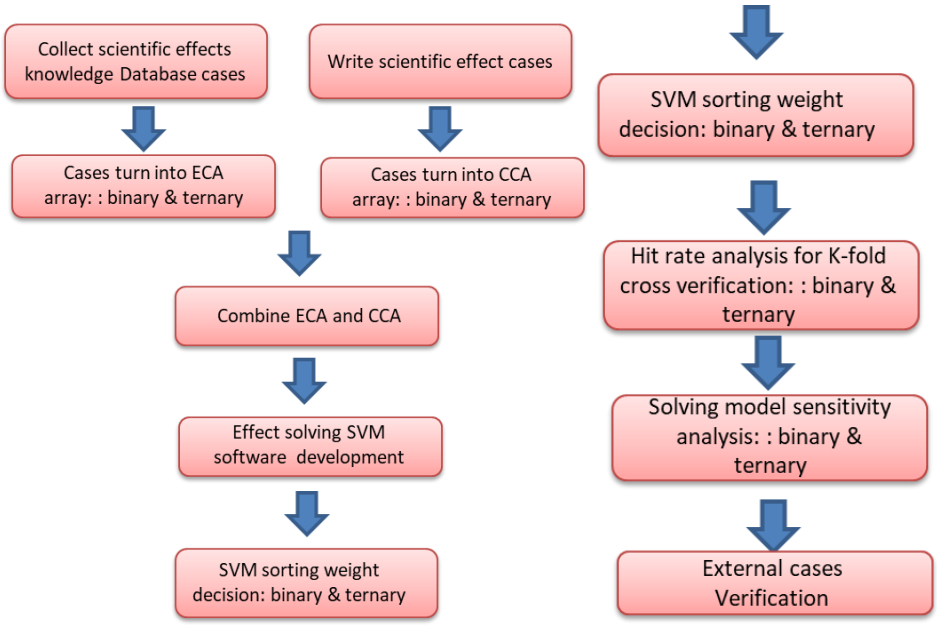

FIG. 1.1 TRIZ effect solution research process

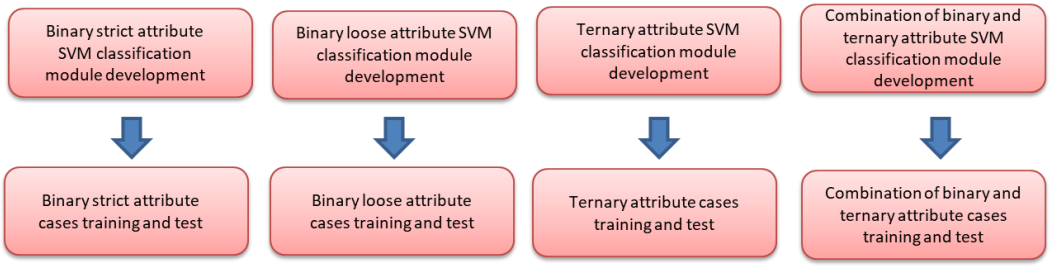

FIG. 1.2.1、Attribute SVM classification module

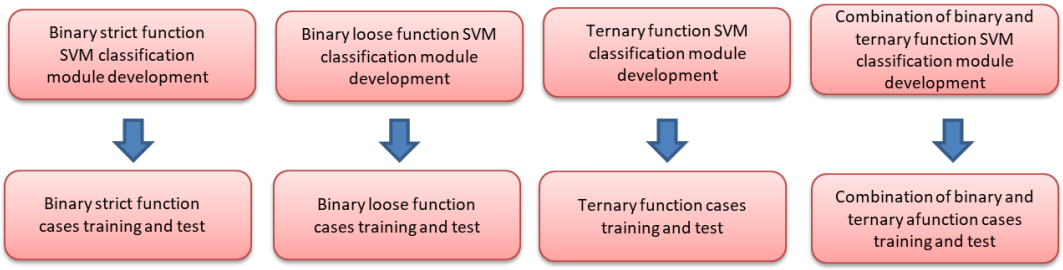

FIG. 1.2.2 Function SVM classification module

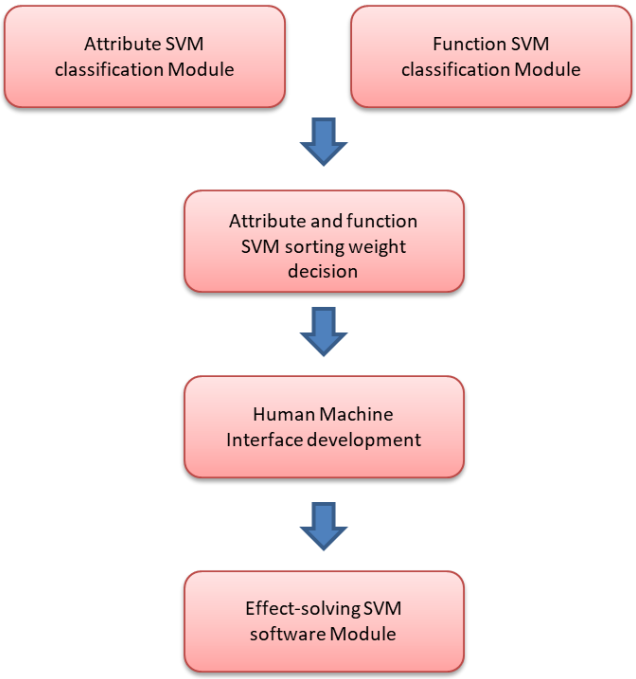

FIG. 1.2.2 SVM module development process

III. Research methods and process

(1) The effect database quantitative problem solving. process

Before using SVM algorithm, it is necessary to establish a training set and test set with a sufficient sample size, since the final purpose of the model is to assist in the analysis of the TRIZ problem, our sample data must also be composed of the TRIZ problem, so the research from the network to collect the solved innovation cases, as well as the application cases of each effect in the effect knowledge base, as training materials. The collected cases mostly describe the problem situation and solution in words, and in order to facilitate the operation, they should be converted into numerical forms that support the understanding of vector machine models. After quoting the quantitative design method of Chiu, Sheng-Chia (2013), this study conducted "attribute function analysis" on the cases respectively, and obtained the "characteristic attributes", "indirect functions" and "direct functions", and then used these three as characteristics to describe the problem, and converted the case content into a common numerical style in the form of "arrays".

(2).Attribute and function parameter definitions

(a). A binary and strict approach

In the process of "attribute-function analysis", the attributes and functional parameters in the effect are defined in a "strict" way, and only the absolutely necessary attributes and functions are selected and taken into account to solve the problem. If the study cannot determine whether the attribute and functionality are related to the problem, it is considered unrelated. This way of defining functions and attributes is the concept of "binary", which is represented by "1" if the property or function is related to the problem; conversely, it is represented by "0".

(b). A binary and loose approach

In the process of "attribute-function analysis", the attributes and functional parameters in the effect are defined in a "loose" way, and if the properties and functions are likely or determined to involve system problems, they will be taken into account to solve the problem. If the study cannot determine whether the attribute and function are not related to the problem, it is always considered related. This way of defining functions and attributes is the concept of "binary", which is represented by "1" if the property or function is related to the problem; conversely, it is represented by "0".

(c). A Ternary approach

When doing "attribute-function analysis", define the function and attribute parameters with the method and concept of "ternary fuzziness". If the function or attribute involves a deeper system problem, the higher the degree of correlation with the problem, that is, the higher the value; if a function or attribute involves a deeper system problem, the lower the correlation with the problem, the lower the value. This way of defining functions and attributes is the concept of "ternary", which is represented by "1" if the property or function is related to the problem; Regardless of "0"; some correlations are represented by 0.5.

It can be seen that this study discusses the definition of "properties and functions" into three situations (methods), and its architecture is shown in table 3.1 and figure 3.1 as below:

Table 3.1 Attribute and function analysis

Definition method	Corresponding value when attribute or characteristic with relation to the problem	Corresponding value when attribute or characteristic with relation to the problem	Corresponding value when attribute or characteristic with relation to the problem
Binary Strict	1	0	0
Binary Loose	1	1	0
Ternary Fuzzy	1	0.5	0

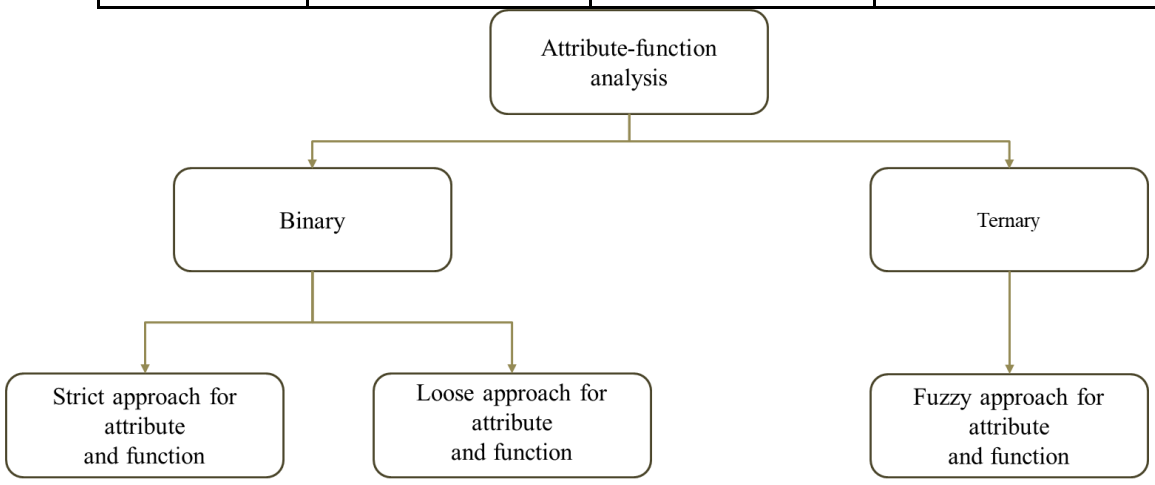

FIG. 3.1 SVM module development process

(3). Problem characteristic array (PCA): Problem patterning

The PCA describes the characteristics of the problem, and after standardized izing the problem, clearly shows the problem content, so that the problem can be compared and analyzed in a mathematical and physical way, and the data can be easily stored in the database, and can also be used by other intelligence tools.

The PCA contains the attribute array and the function array, and the attribute and function parameters are expressed in a mathematical way, the attribute array represents the problem-related characteristics, and the function array is divided into two parts, one part is the direct function array, which represents the function that the problem needs to achieve; The indirect function array represents a change or maintenance of the attribute to solve the problem, as shown in table 3.2 table:

Table 3.2 the list of problem characteristic arrays based on attributes and function

PCA												
Problem Number	Attribute Arry				Function Arry							
					Indirect Function				Direct Function			
	1	2	…	P	1	2	…	P	1	2	…	K
i												

- Binary classification: In binary arrays, 1 or 0 is used to represent "attribute elements" and "functional elements" that are "related" or "unrelated".
- Ternary classification: In ternary classification, 1, 0.5 and 0 represent "attribute elements" and "functional elements" that are "associated", "partially related" or "unrelated".

(4). Solution characteristic array (SCA)

This study collects a large number of past cases, and each case has a corresponding solution, SCA aims to transform the solution into a numerical language that can be understood by the computer, in the format shown in table 3.3, which is an array structure of one NN row, where NN is the total number of effects, and each row in the array represents an effect.

Table 3.3 the list of solution characteristic arrays based on attributes and function

SCA					
Effect 1	Effect 2	…	Effect nn	…	Effect NN
$s1$	$s2$		sn		sN

When sn is "1" in the array, it represents the effect nn as one of the solutions to this case model; When sn is "0", it means that the effect nn cannot be used as an solution for this case model, and so on. The SCA in the cumulative data of this study determines 1 or 0 based on the question "whether the effect has been applied and successfully solved in this case" so far.

(5). Case characteristic array (CCA):

The CCA aims to translate the content of each case we collect into a numerical language that can be understood by computers, so each case must have a 1-column array of case characteristics.

The CCA consists of a PCA and an SCA, and the schema is shown in Table 3.4 as below, where K is the total number of existing attribute species; P is the total number of existing functional categories; N is the total number of effects; M is the total number of cases.

Table 3.4 the list of case characteristic arrays based on attributes and function

	CCA															
	PCA												SCA			
Case	Attribute array				Function array								Solution array			
					Indirect function				Direct function							
	1	2	…	P	1	2	…	P	1	2	…	K	1	2	…	N
1																
2																
⋮																
C																

(6). Effect characteristic array (ECA):

In this study, in addition to practical application cases of various effects, we will also use the effects themselves as part of the training material. The ECA is the transformation of the properties of each effect into a numerical language that the computer can understand, so each effect must have a 1-column array of effect characteristic. The format of the effect characteristic array is shown in Table 3.5, where K is the total number of existing attribute species; P is the total number of existing function categories; N is the total number of effects. It is not difficult to find that its format is roughly the same as that of the case characteristic array, but there are slight differences in the definition of the values within the array.

Table 3.5 the list of effect characteristic arrays based on attributes and function

ECA													
	PCA									SCA			
Effect	Attribute array			Function array									
				Indirect function			Direct function						
	1	…	*K*	1	…	*K*	1	…	*P*	1	2	…	M
1										1	0		0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
M										0	0		1

(7). Introduction to the SVM Model of the effect solution

(a). SVM classification concept

When standardized arrays is classified by SVM, you need to test the PCA with a trained dataset that contains case arrays and effect characteristic arrays.

Based on the theory of TRIZ, "similar problems have similar solutions", we use the SVM to find the solved questions that are similar to the problems, and then use the solved problems to find similar solutions. In the past problem solving experience, we found that function arrays are more important than attribute arrays, so we use two types of classifiers: attribute classifiers and function classifiers.

The PCA is paired with two classifiers to get two scores, multiplied by the weight values of the functions and attributes, and prioritizes the solution model according to the last weighted score. At the same time, in order to cooperate with the problem solvers to propose the possibility of having three different PCA of binary loose, binary strict, and ternary fuzzy, coupled with the integration of binary and ternary, this study will have a total of four types of PCA as research objectives, the detailed steps are as follows:

- Step1: The cases and effects are sequentially integrated into four kinds of individual state CCA and ECA using binary loose, binary strict, ternary fuzzy and binary and ternary elements, and trained according to 104 effects respectively, and 104 attribute classifiers and functional classifiers are obtained respectively. Each classifier gets a decision function.
- Step2: Substitute the function part of the PCA into a decision function in the functional classifier.
- Step3: If the PCA under test is labeled "+1", the case of this effect can be used as a solution to the question. In addition, according to the classification of SVM, the farther the classified data point is from the distinguishing plane, the better the classification effect, that is, the decision value obtained after the problem is substituted into the classifier decision function. The decision value is an important basis for subsequent sorting.
- Step4: Substitute the attribute part of the PCA into a decision function in the attribute classifier.
- Step5: If the PCA under test is labeled "+1", the case of this effect can be used as a solution to the question. In addition, according to the classification of the support vector machine, the farther the classified data point is from the distinguishing plane, the better the classification effect, that is, the decision value obtained after the problem is substituted into the classifier decision function. The decision value is an important basis for subsequent sorting.
- Step6: Multiply the decision value obtained from step three by the function weight, and multiply the decision value obtained by step five by the attribute weight, and add the two.
- Step7: After all effects have been tested, the effect solutions are sorted according to the weighted score results of step six. The higher the order of the solution, the more likely it is

to be used as the solution model for a particular question. According to this concept, the solution model of a specific problem can be found from the solution database, and the overall architecture of the calculation method is shown in Figure 3.2.

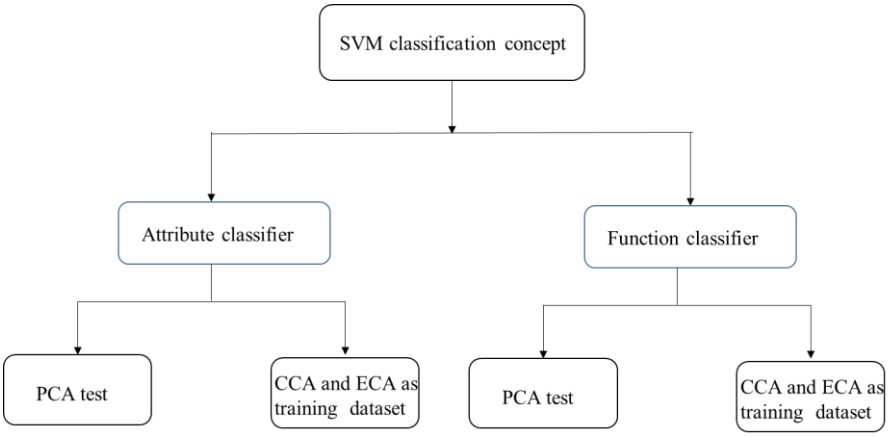

FIG. 3.2 Application of the classification method of the support vector machine to the architecture of the effect knowledge base theory

IV. Software Architecture

The software structure of this study supports the machine learning and analysis part of the vector machine for the R language, and the writing interface is R-shiny.

The interface is divided into three parts, the first part is the home page, which introduces the basics, purposes and use of the software; The second part is to enter the problem model in the standardized problem model format provided for this study, and then use the software to find effect solutions; The second part is to select properties and functions using the interfaces provided by the software.

(a). Homepage

The home page describes the purpose of the software, the problem feature array, and the steps to use the software. The home page is shown in Figure 4.1:

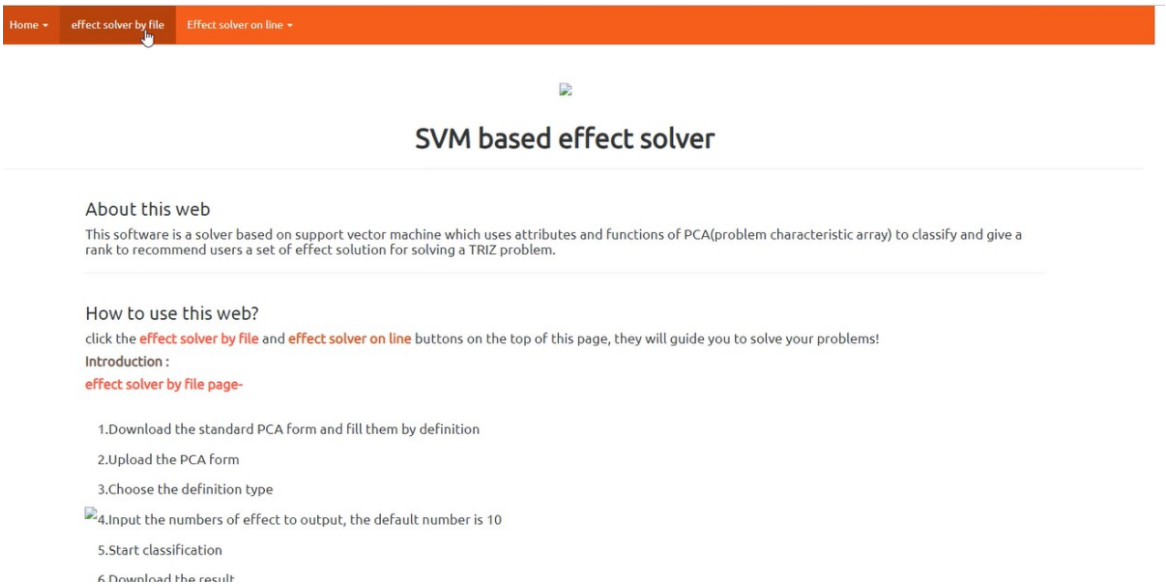

FIG. 4.1 Software homepage

(b). File input interface for the problem model

The software provides two ways to input the PCA, and only need to click the button in the upper bar of the software to switch:

(i) The system provides a standardized PCA to the user, which is then externally upload to the software, and finally enter the number of solution models you want to get, you can analyze. Among them, the number of output solution models recommended in this study is 20. The external file input interface is shown in Figure 4.2:

(ii) The interface designed for this study allows users to directly select the relevant attributes and functions, and finally enter the number of solution models they want to obtain for analysis. Among them, the number of output solution models recommended in this study is 20. The software page input interface is shown in Figure 4.3.

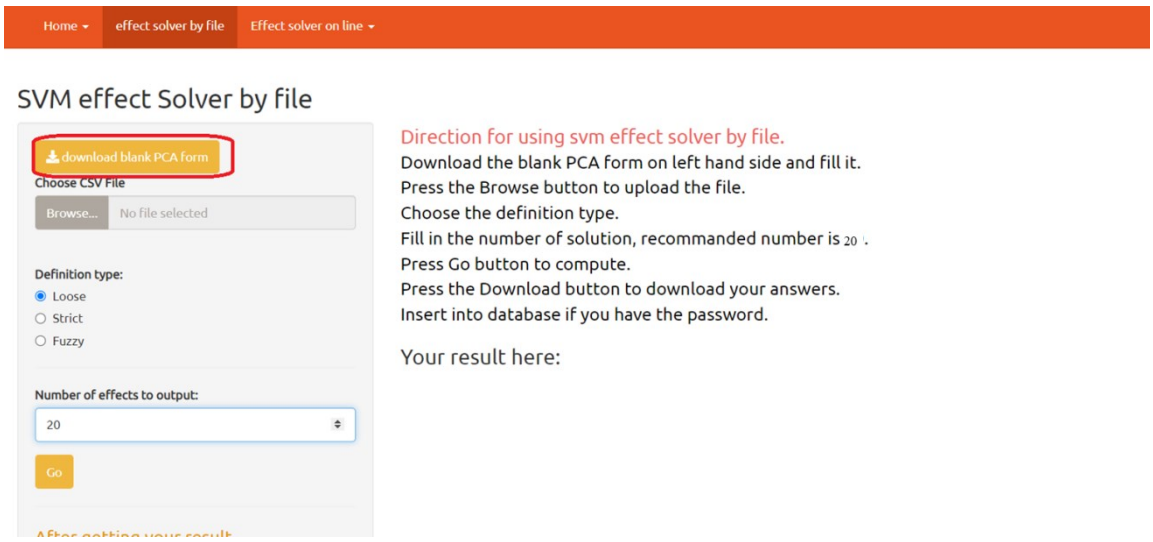

FIG. 4.2 a standardized PCA download

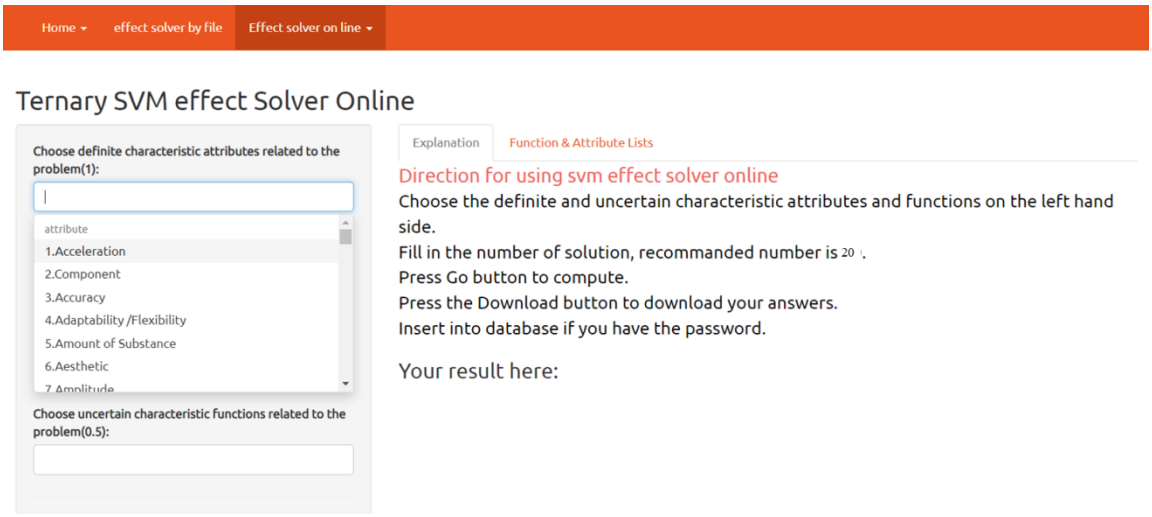

FIG. 4.3 The relevant attributes and functions selection

(c). Output interface for the solution model

After the software performs the effect classification calculation of SVM, it will output a set of solution models with priority, the priority order is sorted from high to low, and the user is objectively recommended to select the effect to solve the problem. The example of output interface for solution model is shown in Figure 4.4:

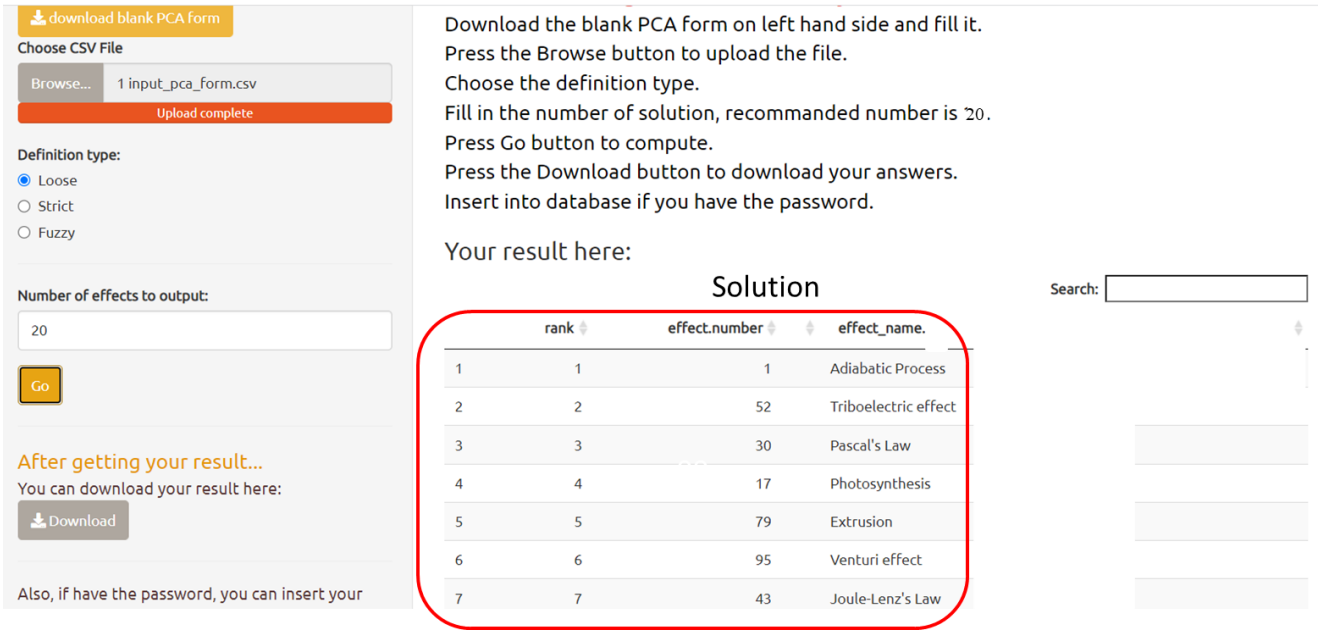

FIG. 4.4 Output interface for the solution model

V. Summary

With the help of mathematical, physical and chemical arrays and machine learning, replacing humans with cumbersome calculations and searches, the inconvenience of the process can be greatly improved. Compared with traditional methods, the effect search method proposed by this study has the following improvements.

(1) Significantly reduce the time it takes to convert a "problem model" into an "answer model". In the past, analysts had to search the knowledge base one by one and judge whether each effect was compatible with the problem; The current research model can accurately and directly produce the optimal effect solution and improve the solution efficiency.

(2) Establish a computer-aided system that recommends users to use the effect database to solve problems in the form of machine learning, and advises users to choose effect from the perspective of mathematical analysis, so as to avoid excessive reliance on expert experience and models that can be quickly and objectively solved.

(3) Establish a user interface to provide users with input data to solve the problem array, obtain a set of effect solution models with priority, assist users in selecting the best effect solution, and provide users with this solution output

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The 13th International Conference on Systematic Innovation

Proceedings

Editors	The Society of Systematic Innovation & International Journal of Systematic Innovation
Publisher	The Society of Systematic Innovation
TEL	+ 886-3-572-3200
FAX	+ 886-3-572-3210
Address	5F, No.350,Sec. 2, Guan-Fu Rd, Hsinchu, Taiwan 30071, R.O.C.

ISBN :978-986-98016-9-0

2022/10/15

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