

Research status and development of tractor cab modeling design theory

Ruitong Gao, He Zhu, Yanhao Li, Li Wang, Shuhang Zhao¹

¹(School of Agricultural Engineering And Food Science, Shandong University of Technology, Zibo, 255000, China.)

Abstract: With the rapid development of agricultural and industrial design, product design based on user needs began to come to people's eyes. As the most commonly used and common mechanical product in agricultural operation, various functions of tractor are constantly improved and perfected. However, most tractors pay more attention to the needs of farmland operation, but do not dig deeply into the needs of drivers. They really design the tractor cab shape centered on users. This paper summarizes the research status of user behavior analysis methods and TRIZ theory, deeply excavates the explicit and implicit needs of drivers, and obtains the design principles of tractor cab modeling design.

Key Word: industrial design, behavior analysis, TRIZ, Tractor, Cab modeling

Date of Submission: 14-01-2022

Date of Acceptance: 29-01-2022

I. Introduction

At present, most agricultural machinery equipment enterprises in the domestic market take performance and machinery itself as the main research objects, and lack of user-centered modeling design research. The research on agricultural machinery in developed countries started earlier, and the development level of some high-performance and new technology products is stable and mature, while the domestic development is just the opposite. At present, China is in a critical period of rapid economic development. Compared with developed countries, agricultural infrastructure, agricultural machinery supporting equipment and agricultural machinery guarantee facilities are relatively backward, and the types of tractor products are single. Agricultural production and food demand have become one of the concerns of today's society and even countries all over the world. With the rapid growth of agricultural machinery market, farmers' demand is also changing quietly. Therefore, the design of agricultural machinery equipment modeling and the needs of farmers have become important and difficult. In the process of product modeling design, we should not only meet the needs of agricultural production, but also consider whether the design itself conforms to the principles of ergonomics and the subjective feelings of users. The success of a product is not judged by the designer, but determined by the user. In industrial design, user centered design has become the main design means. Based on this, the method based on user behavior analysis can enable designers to more comprehensively understand user needs and excavate design pain points.

II. Behavior analysis

II.I. Behavioral analysis theory concept

Behavioral science theory takes human behavior and its causes as the specific research object, and mainly studies human behavior from human needs, motivation, purpose and other factors^[1] As a subjective factor that will make itself produce internal changes and external reactions under the influence of the outside world, man is of great significance in the research of ergonomics. The purpose and needs of man can be obtained by studying man's behavior. User behavior analysis is not a single research content. It involves the cross research of many disciplines, such as image processing, man-machine simulation analysis, psychology, neurology and so on. The two important aspects of behavior analysis from the beginning to the present are description and identification. It studies the psychological and physiological changes formed by the interaction between human behavior and machinery or environment as a whole, forming a complete research route of "man machine system". By studying human behavior, we can better grasp the law of user behavior and deeply understand user needs, and make designers have a deeper understanding of user behavior habits, so as to find and solve problems more efficiently and provide ideas for the design process^[2].

II.II. Acquisition method of user behavior analysis

When using user behavior analysis theory to design products, the acquisition method of user behavior is the center of the design process. The acquisition of user behavior can be carried out through a series of scientific and systematic methods:

- i. **Low level image information acquisition method.** The generalized low-level image information acquisition method refers to the process of imaging an object. Image acquisition in this research method refers to analyzing and processing the target obtained by lens and other equipment on the computer and converting it into digital image information. Based on this method, simple behavior information can be obtained quickly.
- ii. **Questionnaire survey method.** The questionnaire survey method is also called "written survey method" or "form filling method". An investigative method of indirectly collecting research materials in written form or online. It is a method of indirectly obtaining materials and information by sending a concise inquiry form (form) to the investigator for instructions and filling in opinions and suggestions on relevant issues. Online survey methods include QR code and system survey, which is an access method of questionnaire survey. This type of survey method has changed the traditional methods of face-to-face survey, telephone survey, mail survey and e-mail survey, and broken the restrictions of traditional passive survey methods on equipment, time and environment; Respondents can scan the code with their mobile terminal equipment anytime and anywhere to participate in the survey, which greatly reduces the resistance and cost of respondents to participate in the survey; Through the breakpoint continuation function (you can continue to answer after you exit part of the answer and log in next time), you can also effectively use the fragmentation time of the survey object.
- iii. **Interview method.** Interview method refers to a job analysis method in which job analysts deepen their understanding of research work and obtain job information through face-to-face communication with interviewees. The specific methods include individual interview, group interview of the same kind of research and supervisor interview. According to the needs of the survey, the interviewers put forward relevant questions to the interviewees in oral form, and collected objective factual materials through the answers of the interviewees. This survey method is flexible, convenient and feasible, and can understand different types of materials from different types of people according to the needs of the research.
- iv. **Acquisition method of high-rise human structure.** Various postures presented by human body structure are called high-level human body structure information. This method can describe human behavior more accurately. The behavior information acquisition method based on high-rise human structure is complex. People in the target area do specific target pose acquisition. This method can describe the human behavior process more accurately and physically.

II.III. Research status of behavioral analysis theory

i. **Research status abroad.** Applied behavior analysis (J, abbreviated as ABA) originated from Professor LVAr Iovaas in the United States. At that time, the behavior analysis theory was not applied to design, but to the treatment of autistic children. Applied behavior analysis is to decompose the target task (i.e. teaching knowledge, skills, behaviors, habits, etc.) into a series of small or relatively independent steps in a certain way and order, and then use appropriate reinforcement methods to gradually train each small step in the order determined by task decomposition until children master all steps and can finally complete the task independently, And be able to apply the knowledge and skills they have learned in other occasions. Since 1962, not only professor Lovas and his colleagues have been tracking and reporting on the research project, but also a large number of researchers and workers have been formed in the field of special education all over the world. Later, experts and scholars in various fields extended their application on this basis, combined behavior analysis with industrial design, and widely used in different fields (such as human-computer interaction, virtual reality, intelligent monitoring, etc.).

In 1975, Johansson proved through experiments that human behavior can be described only by the movement of several points on the human body^[3]. In 1997, Carnegie Mellon University and Massachusetts Institute of Technology participated in the U.S. Defense advanced research project. The major visual surveillance project VSAM (visual surveillance and monitoring) mainly studies automatic video understanding technology for battlefield and ordinary civilian scene monitoring^[4]. In 1998, Grimson began to monitor abnormal behaviors in monitoring based on behavior analysis theory^[5]. In 2003, David wrote a textbook covering the basic principles of behavior analysis and learning behavior^[6]. In 2005, Yilmaz proposed using STV (spatial temporary volume) to describe behavior^[7]. In 2006, vanderhaegen applied behavior analysis theory to evaluate the behavior of automobile drivers and established a cost model^[8]. In 2014, critchfield wrote an article on ten principles of behavior analysis, which caused a lot of discussion among researchers and experts^[9]. In 2016, Tabata et al. Proposed a method to analyze workers' behavior based on indoor positioning technology and workplace field testing^[10]. In 2021, pietrykowski et al. Used data mining to analyze the navigator's behavior and verified the behavior mode of determining the navigator's safety profile in order to prevent marine accidents^[11].

Through reading the literature, it is not difficult to find that in recent 50 years, although the behavior analysis theory has been applied to different fields in all walks of life, such as monitoring, automobile design, accident detection and so on. But few people apply it to the design of agricultural machinery.

ii. **Domestic research status.** In 2006, Luo Jianguang and others proposed an application layer multicast tree generation algorithm for live video broadcasting. Simulation results show that the algorithm can significantly reduce the number of data transmission interruptions of application layer multicast tree under live video application^[12]. In 2007, Zheng Ling and Chen both discussed in detail the characteristics and working principle of intelligent search engine technology, analyzed the problems and related solutions in the process of intelligent search engine, and focused on a core implementation technology of intelligent search engine - user behavior analysis technology^[13]. In 2009, Tang Jian designed a cloud computing billing system based on user behavior analysis. It is based on consumption, which can ensure that consumers only pay for the resources they use^[14]. In 2012, Feng Wei introduced the method of user centered design and user behavior observation, defined the user group according to subdivision, observed the user behavior, analyzed and summarized the data, and then applied the user behavior analysis to the automobile R & D process in combination with the automobile design program^[15]. In 2015, based on the basic theory of customer demand analysis, Lin Weijie and others introduced the main process of industrial design of a notebook color ultrasonic diagnostic equipment, and expounded how medical ultrasonic products can realize and meet the needs of customers for aesthetics and ease of use^[16]. In 2016, Liu yinglu introduced and studied the concept of health industrial design (HID) to guide the research and design of powerless walking aids for the elderly^[17]. In 2018, Ze Rui Xiang et al. Discussed the riding tasks, key riding movements, routes and impact on wheelchair users of wheelchair passengers taking the railway, as well as the typical riding heat load, so as to support the development of general railway passenger car layout and evaluate its effectiveness^[18]. In 2019, based on the research on the driver's active driving behavior, Ou Jing and others can systematically carry out ergonomic analysis to provide effective guidance for the modeling design of forklift cab^[19]. In 2020, Guo Jing introduced the method of user behavior analysis to conduct innovative design research on the kitchen layout and products of target users such as young users, so as to provide new ideas for kitchen design^[20].

To sum up, most domestic experts and scholars will apply behavior analysis theory to search engines, algorithms, user behavior models and automobile design and development. Some scholars also apply behavior analysis to high-speed railway layout design and forklift modeling design, but few scholars apply it to tractor cab modeling design.

III. TRIZ theory

III.I TRIZ theory concept

TRIZ theory was founded by G. S. Altshuller in 1946. Altshuller is also honored as the father of TRIZ. In the following decades, Altshuller devoted his whole life to the research and improvement of TRIZ theory. Under his leadership, research institutions, universities and enterprises of the former Soviet Union formed a research group of TRIZ, analyzed nearly 2.5 million high-level invention patents in the world, summarized the laws and patterns followed by the development and evolution of various technologies, as well as the innovative principles and rules to solve various technical and physical contradictions, and established a variety of methods to solve technology and realize innovative development. The TRIZ theoretical system is established by integrating the principles and rules of multi-disciplinary fields. Before the mid-1980s, the theory was kept secret from other countries. In the mid-1980s, with a group of scientists migrating to the United States and other western countries, the theory was gradually introduced to the field of world product development, which has had an important impact on this field.

III.II Research status of TRIZ theory at home and abroad

i. **Research status abroad.** In 1998, systematic innovation (system innovation: an introduction to TRIZ), written by John Terninko and others, was published. This book introduces the theory of creative problem solving (TRIZ), which will stimulate breakthroughs in thinking patterns and problem-solving methods^[21]. In 2003, R. Stratton et al. Collected two parallel but independent invention problem-solving theories: one is mechanical engineering theory, namely Russian invention problem-solving theory (TRIZ), and the other is constraint factor theory (TOC) derived from manufacturing management. They focused on the significance of balancing spear and shield to innovation in these two fields, The relationship between them and the strategic development of manufacturing industry is discussed^[22]. In 2004, Gaetano Cassini et al. Proposed the use of inventive problem solving theory (TRIZ) to redesign structural components from metal to polymer^[23]. In 2005, Julian f.v. Vincent et al. Provided biological information for engineers through TRIZ's "biological patent" database^[24]. In 2011, Gheorghe burz et al. Constructed an expert system. The expert system of TRIZ method can select the invention principle from the contradiction matrix according to 39 parameters that may conflict, and then provide examples, incoming details and other relevant projects generated by experience for each selected invention principle^[25]. In

2012, Denny nurkertamanda and others optimized the starting block of the swimming pool based on the TRIZ principle to make the starting block suitable for all athletes of any age and adapt to the condition of the water surface^[26]. In 2013, Macht et al. Improved the typical TRIZ Method and proposed an algorithm to systematically simplify the considered parameters into manageable sets^[27]. In 2017, Roman teplov et al. Conducted a systematic literature review of academic articles on TRIZ based innovation methods. The research results confirmed the subjectivity of the solution and its dependence on previous user experience, filling the gap in the application of TRIZ in innovation management^[28]. In 2020, Alberto et al. Proposed a new method to design the export packaging of Persian lime by using the mathematical model optimized by genetic algorithm and coordinating with the Russian theory of problem solving and invention (TRIZ)^[29].

ii. **Domestic research status.** The research and application of TRIZ theory in China started relatively late. In 1999, Niu Zhanwen and others published the first article "scientific methodology of invention and creation - TRIZ" in China mechanical engineering. The article mainly introduces the principle of TRIZ. TRIZ is a scientific process for people to think and solve problems, and provides a correct exploration direction for creative solution of problems^[30]. In 2001, Ma Huaiyu and others put forward an integrated model of conceptual design process based on QFD, function analysis (FA) and TRIZ through the research and application of TRIZ innovation theory, quality function configuration (QFD) and other design methods, and conducted an example analysis of a simple spinning mechanism, which achieved the expected effect^[31]. In 2004, Zhang Fuying and others explored the evolutionary potential of hydraulic cylinder moving seal based on the integration of TRIZ's evolutionary route and evolutionary potential, pointing out the direction for the future development of hydraulic cylinder moving seal^[32]. In 2007, Wang Jianfeng and others made a specific study on the fruit picking robot by using TRIZ theory, analyzed and improved the manipulator and end effector, established a soft fruit harvesting robot model that only grasped the fruit stem without direct contact with the fruit body, and solved some problems of the fruit picking robot in the fruit picking process^[33]. In 2008, based on the analysis of a large number of documents, Zhao Wenyan and others proposed an application process of TRIZ in management process optimization - dtsc (define translate solve improve control), which effectively combines the management method with TRIZ principle and toolkit, Improve the process during continuous circulation^[34]. In 2010, Han Shanling and others carried out the innovative design of C-shaped frame of self piercing riveting machine based on TRIZ theory, and designed a C-shaped frame with adjustable throat depth, which improves the working flexibility of self piercing riveting machine. It solves the problem of fixing the throat depth of the C-shaped frame of the traditional self piercing riveting machine^[35]. In 2013, Liu Taotao built a CAI system supporting product innovation design based on TRIZ theory, using Visual Basic as the system development platform, combined with access technology and HTML technology, analyzed the functional model of internal combustion engine vehicle, found out its harmful functions and eliminated them^[36]. In 2020, sun Ning and others established a technology maturity prediction model of chemical process system based on TRIZ technology system evolution theory, which can guide China's chemical industry practitioners to carry out relevant technology development^[37]. In 2021, Qi Zhuhui and others studied the "physical field analysis" model of reed bunching process and binding process by using TRIZ theory, established the reed high vertical sand barrier binding system, and improved and manufactured the reed high vertical sand barrier binding prototype with adjustable parameters^[38].

To sum up, domestic and foreign experts, scholars and other research teams have applied TRIZ theory to the fields of expert system, database algorithm, auto parts, automatic riveting machine and strapping machine. Although they are involved in the field of agricultural machinery and equipment, few research teams have applied it to the modeling design of tractor cab.

IV. Summary

The demand of agricultural machinery drivers has attracted more and more attention from designers and users, and the design of agricultural machinery products needs to be continuously optimized by designers. According to the survey, the market development of agricultural machinery products is far from catching up with diversified agricultural production methods. At present, the product design and R & D for agricultural machinery drivers in the market lags behind the product demand of agricultural production groups, and the design and performance of many agricultural machinery products are still stagnant. The vast majority of products in the market only consider the cost performance and universality, and pay less attention to the physiological and psychological characteristics and personalized needs of agricultural machinery drivers. Now the tractor design is developing towards unmanned and intelligent, so there is a design fault in the middle. Designers generally focus on new unmanned tractors, and basically no one takes out the existing products in the market for innovation and re optimization.

Therefore, for agricultural machinery products, we should not only meet the performance needs of agricultural machinery in operation, but also meet the emotional needs and comfort needs of agricultural machinery drivers in use. Combined with relevant literature reference and research, it is concluded that the design principles of tractor cab are as follows:

- i. **Safety principle.**In the design process of agricultural machinery products, safety is one of the primary criteria of the whole machinery design. The working environment, physiological and psychological state of the driver during operation are not invariable, and there will be emergencies at any time. Therefore, the safety requirements of the product are very high. The designer shall effectively avoid potential safety hazards due to unreasonable layout and materials.
- ii. **Comfort principle.**The design of agricultural machinery products should be fully combined with the characteristics of environment and people, and meet the needs of actual users. Agricultural machinery drivers often face high-intensity operation requirements during operation. Drivers are easy to be tired due to an operation posture maintained for a long time. Therefore, in the design process, targeted and group research should be done for this group of users, so that the designed products can meet the needs of users and improve the comfort of users at the same time.
- iii. **Functional principle.**For agricultural producers, the functionality of products is also their focus. In front of this principle, other principles are auxiliary principles. Only by taking the functional principle as the main body and echoing other auxiliary principles can the overall diversified design of the product be completed.

References

- [1]. Zhang Qianqian. On the theory of behavioral science[J].Contemporary agricultural machinery, 2021 (05): 77-79
- [2]. Li Yafei. Research on refrigerator design based on user behavior analysis[D]. Shandong University, 2015
- [3]. Johansson G. Visual motion perception [J]. Scientific American, 1975, 232(2) : 76-88.
- [4]. Wang Liang, Hu Wei-ming, Tan Tie-niu. A survey of visual analysis of human motion[J]. Chinese Journal of Computers, 2002, 25(3): 225-237..
- [5]. Crimson W E L, Stauffer C, Romano R, et al. Using adaptive tacking to classify and monitor activities in a site [A]. In: Proceedings of IEEE Conference on Computer Vision and Pattern Recognition [C], Santa Barbara, California, USA, 1998 : 22-29.
- [6]. W. David Pierce, Carl D. Cheney. Behavior Analysis and Learning[M]. Taylor and Francis: 2003-08-01.
- [7]. Yilmaz Alper, Shah Mubarak. Actions sketch: A novel action representation [A]. In: Proceedings of IEEE Conference on Computer Vision and Pattern Recognition [C], San Diego, California, USA, 2005 : 984-989. Zhao Guang. Formation Mechanism Analysis of Driving Fatigue Risk Based on Capability Matching [D]. Dalian University of Technology, 2018.
- [8]. F. Vanderhaegen, S. Chalmé, F. Anceaux, P. Millot. Principles of cooperation and competition: application to car driver behavior analysis. [J]. Cognition, Technology & Work, 2006, 8(3):
- [9]. Critchfield Thomas S. Ten Rules for Discussing Behavior Analysis. [J]. Behavior analysis in practice, 2014, 7(2):
- [10]. K. Tabata, H. Konno, M. Nakajima. THE DESIGN OF WORKER'S BEHAVIOR ANALYSIS METHOD IN WORKPLACE USING INDOOR POSITIONING TECHNOLOGY [J]. ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, 2016, III-4:
- [11]. Zbigniew Pietrzykowski, Mirosław Wielgosz, Marcin Breitsprecher. Navigators' Behavior Analysis Using Data Mining [J]. Journal of Marine Science and Engineering, 2020, 8(1):
- [12]. Luo Jianguang, Zhao Li, Yang Shiqiang Application layer multicast tree generation algorithm based on user behavior analysis [J]. Computer research and development, 2006 (09): 1557-1563.
- [13]. Zheng Ling, Chen Du Application of user behavior analysis in intelligent search [J]. China Electric Power Education, 2007 (S1): 386-387.
- [14]. Tang Jian Analysis and design of cloud computing billing system based on user behavior analysis [J]. LIAONING ECONOMIC VOCATIONAL AND TECHNICAL COLLEGE (JOURNAL OF LIAONING ECONOMIC MANAGEMENT CADRE COLLEGE), 2009 (05): 46-47.
- [15]. Feng Wei Car research and design based on young users' car behavior [D] Wuhan University of technology, 2012.
- [16]. Lin Weijie, Xu Shixiong, Su Shudian Industrial design of medical ultrasonic products based on customer demand analysis [J] China medical device information, 2015, 21 (06): 27-31 + 34.
- [17]. Liu Yinglu Research on the design of powerless aids for the elderly based on the concept of "hid" [D] Yanshan University, 2016.
- [18]. Xiang Z R, Zhi J Y, Dong s y, etc. Influence of ergonomics / human factors of wheelchair / user combination on effective barrier free environment design: a case study of general railway passenger car layout in China [J]. International Journal of Industrial Ergonomics, 2018, 67: 229-241.
- [19]. Ou Jing, Zheng yunshuang, Zhao Jianghong, Yi Jun Research on Modeling Design of forklift cab based on behavior analysis [J] Packaging engineering, 2019, 40 (14): 128-134.
- [20]. Guo Jing Research on kitchen layout and product design based on user behavior analysis [D] Zhejiang University of technology, 2020.
- [21]. John Terninko, Alla Zusman, Boris Zlotin. Systematic Innovation [M]. Taylor and Francis; CRC Press: 1998-04-15.
- [22]. R. Stratton, D. Mann. Systematic innovation and the underlying principles behind TRIZ and TOC [J]. Journal of Materials Processing Tech., 2003, 139(1):
- [23]. Gaetano Cascini, Paolo Rissone. Plastics design: integrating TRIZ creativity and semantic knowledge portals [J]. Journal of Engineering Design, 2004, 15(4):
- [24]. Julian F. V. Vincent, Olga Bogatyreva, Anja- Karina Pahl, Nikolay Bogatyrev, Adrian Bowyer. Putting Biology into TRIZ: A Database of Biological Effects [J]. Creativity and Innovation Management, 2005, 14(1):
- [25]. Gheorghe Burz, Liviu Marian. Research on an expert system for TRIZ Method applying [J]. Scientific Bulletin of the "Petru Maior" University of Tîrgu Mureş, 2011, 8 (XXV)(1):
- [26]. Denny Nurkertamanda, Asen Ahman. PENGEMBANGAN DESAIN STARTING BLOCK KOLAM RENANG DENGAN MENGGUNAKAN THEORY OF INVENTIVE PROBLEM SOLVING (TRIZ) [J]. Teknik, 2012, 31(1):
- [27]. Macht, Gretchen A, Okudan Kremer, Gül E, Nembhard, David A. Alternative Methodology for TRIZ Implementation [J]. IIE Annual Conference. Proceedings, 2013:
- [28]. Roman Teplov, Leonid Chechurin, Daria Podmetina. TRIZ as innovation management tool: insights from academic literature [J]. Int. J. of Technology Marketing, 2017, 12(3):
- [29]. Alberto Alfonso Aguilar-Lasserre, Víctor Eduardo Torres-Sánchez, Gregorio Fernández-Lambert, Catherine Azzaro-Pantel, Guillermo Cortes-Robles, Missael Alberto Román-del Valle. Functional optimization of a Persian lime packing using TRIZ and multi-objective genetic algorithms [J]. Computers & Industrial Engineering, 2020, 139:

- [30]. Niu Zhanwen, Xu Yanshen, Lin Yue, Guo Jianqiang, Li Li Scientific methodology of invention -- TRIZ [J] China Mechanical Engineering, 1999 (01): 92-97 + 7.
- [31]. Ma Huaiyu, Meng Mingchen Product conceptual design process model based on TRIZ / QFD / fa [J] Journal of Tsinghua University (NATURAL SCIENCE EDITION), 2001 (11): 56-59.
- [32]. Zhang Fuying, Xu Yanshen Evolutionary research on moving seal of hydraulic cylinder based on TRIZ [J] Lubrication and sealing, 2004 (03): 14-17.
- [33]. Wang Jianfeng, Ge Zhenyang, Zhu Huibin Research on fruit picking robot based on TRIZ theory [J] Research on agricultural mechanization, 2007 (06): 34-36 + 59.
- [34]. Zhao Wenyan, Zhang Changgao, Tan Runhua, he Zhen Application of TRIZ in management process optimization [J] Journal of engineering design, 2008 (02): 79-85.
- [35]. Han Shanling, Yang Lei, Gao Libo, Zhong Peisi Innovative design of C-frame of self piercing riveting machine based on TRIZ theory [J] Coal mining machinery, 2010,31 (09): 34-36.
- [36]. Liu Tao Research on key parts of aerodynamic vehicle based on TRIZ [D] Shandong University, 2013.
- [37]. Sun Ning, Zhou Guangwen, Zhang Qingqing, Yang Xia Technology maturity prediction model of chemical process system based on TRIZ theory [J / OL] Computer and applied chemistry, 2020 (02): 140-146 [2021-11-29]
- [38]. Qi Zhuhui, Ge Yun, Zheng Yijiang, Zhang Yuyu, Cheng Jianjun Design and test of reed high vertical sand barrier binding system based on TRIZ theory [J] Mechanical design and research, 2021,37 (01): 183-189

Ruitong Gao, et. al. "Research status and development of tractor cab modeling design theory." *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, 15(01), 2022, pp. 51-56.