User Requirements Analysis and Model Optimization Based on Machine Vision in Cultural and Creative Product Design

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Abstract. In Wenchuang (Cultural and Creative) product design, user requirement analysis and computer-aided design (CAD) model optimization based on machine vision technology are efficient design methods. The main purpose of CAD model optimization is to improve the user experience of products, making Wenchuang products more competitive in the market. The results show that the method proposed in this article has high accuracy and recall in user demand analysis and CAD model optimization and can effectively support personalized product design and optimization. Due to the use of deep non-uniform sampling methods, the algorithm can maintain sufficient sampling rates in areas with rich depth features, by introducing machine vision technology. Through accurate requirements analysis results, providing clear directions and suggestions for CAD model optimization. The use of CAD model optimization technology can improve the design quality and user experience of products, making Wenchuang products more competitive in the market.

Keywords: Cultural and Creative; Machine Vision; User Requirements; CAD Model
DOI: https://doi.org/10.14733/cadaps.2024.S15.308-324

1 INTRODUCTION

In today's highly information-based society, Wenchuang products rely more and more on CAD technology in the design process. Machine vision technology is widely used in CAD systems to achieve more accurate and fast 3D modeling. This technology can automatically recognize and extract features from images, greatly improving the efficiency and accuracy of modeling. At the same time, machine vision technology can also achieve automated image processing and recognition, further improving the intelligence level of CAD systems. Secondly, cultural and creative products also play an important role in CAD research. Cultural and creative products often have unique cultural connotations and creativity, which can provide new ideas and inspiration for CAD research. For example, in architectural design, cultural and creative products can provide designers with inspiration for cultural elements and design concepts, thereby designing architectural works with more cultural connotations and artistic value. Finally, machine vision learning and cultural and creative products have a mutually reinforcing role in the progress of CAD research. On the one hand, cultural and creative products can provide a rich dataset and case studies for machine vision learning, thereby promoting the development and application of machine vision technology. On the other hand, machine vision technology can also provide more intelligent and efficient support for production, thereby promoting the development and innovation of the cultural and creative industry [1]. Machine vision technology can also be used to achieve immersive virtual reality experiences. For example, in the field of gaming, machine vision technology can be used to capture players' actions and expressions and then convert them into virtual character actions and expressions in the game, thereby achieving a more realistic gaming experience. At the same time, machine vision technology can also be used to achieve functions such as gesture recognition and object recognition in immersive virtual reality, further enriching the user experience. Machine vision technology can also play an important role. Bernardo and Duarte [2] use machine vision technology to digitally model and simulate products and then use immersive virtual reality technology for product design and evaluation. This design approach can greatly improve design efficiency and quality while also allowing designers to more intuitively experience the appearance and characteristics of products, thereby better carrying out product design and improvement. User demand is one of the most important factors in the process of product design, and accurately grasping user demand can improve the market competitiveness of products. With the rapid development of technology, virtual reality technology has been widely applied in various fields, including tourism product development. Through virtual reality technology, designers can create realistic 3D models, providing more efficient and intuitive design solutions for tourism product development. Deng et al. [3] explored the development of tourism products; virtual reality technology can be used to create three-dimensional models of tourism destinations, providing tourists with more realistic experiences and feelings. CAD 3D modeling system is a computer software system used for design, modeling, and drafting. In the development of tourism products, CAD 3D modeling systems can be used to create 3D models of tourism destinations and to design and adjust the details of the models. Designers can more accurately express their design ideas and improve design efficiency and quality. Designing a tourism product CAD 3D modeling system using virtual reality technology is an innovative way of developing tourism products. Through virtual reality technology and CAD 3D modeling systems, designers can design tourism products more efficiently and intuitively; interactive experiences can allow users to more realistically experience the charm and characteristics of tourism products, providing more accurate market positioning and user feedback for tourism product development. In Wenchuang product design, machine vision technology can be applied to the user requirement analysis stage. By collecting and analyzing information such as user behavior, facial expressions, and feedback, we can deeply explore user needs and preferences, providing a basis for personalized product design. By collecting and analyzing user feedback information, continuous improvement of products can also be carried out to improve user satisfaction. Hu [4] explored the specific applications and advantages. Firstly, the 3D modeling function of AutoCAD provides an intuitive design environment for industrial modeling design. Designers can model in three-dimensional space and intuitively express their design ideas by changing the shape, size, position, and other parameters of the geometry. This three-dimensional modeling method allows designers to express their ideas more freely while reducing possible errors in the conversion process from 2D to 3D. Secondly, AutoCAD's 3D modeling function has efficient modeling tools. By using techniques such as Boolean operations, surface modeling, and solid modeling, designers can quickly create and modify complex geometry. In addition, AutoCAD also provides a wealth of material and mapping tools that can add realistic surface effects to the model as needed. These tools enable designers to create high-quality 3D models. Furthermore, AutoCAD's 3D modeling function is compatible with other CAD software. This allows designers to import data from other software into AutoCAD for processing easily. At the same time, AutoCAD's 3D modeling function also supports multiple output formats, such as STL, STEP, etc., making it easy to export the model to other software for post-processing or analysis.

In cultural and creative product design, the application of machine vision technology, thereby creating products that better meet user expectations and market demands. Machine vision technology can provide deeper user insights for cultural and creative product design by analyzing user behavior and preferences. For example, by analyzing the photos, videos, and other content shared by users on social media, one can understand their preferences and needs for a certain cultural element, thereby providing valuable references for designers. In addition, machine vision technology can also predict users' interests and needs by analyzing data such as purchase history and browsing records, thereby providing more accurate strategies for product design and promotion. Machine vision technology can extract features and styles from cultural elements such as historical relics and cultural heritage through digital scanning and reconstruction and integrate them into cultural and creative product design. This not only enhances the cultural connotation and artistic value of the product, the inheritance and development of traditional culture [5]. In today's educational environment, optimizing classroom layout is a key factor in improving teaching quality and student learning outcomes. However, manually designing classroom layouts is a time-consuming and complex task, making it necessary to develop algorithms that can automatically generate effective classroom layouts. Karadag et al. [6] proposed a classroom layout generation method based on a dual machine learning model, which can automatically generate optimized classroom layouts based on the geometric features of the classroom and students' learning behavior. During the training phase, we collect a large amount of classroom geometric feature data and learning behavior data and then use these data to train our dual machine learning model. We use supervised learning methods to continuously optimize the performance of the model by optimizing the loss function. We conducted experiments using simulated data and actual classroom data and evaluated our model. The experimental results indicate that our dual machine learning model can effectively analyze classroom geometric features, learn students' learning behaviors, and generate optimized classroom layouts. The dual machine learning model proposed in this article supports classroom layout generation, which can automatically generate optimized classroom layouts by analyzing classroom geometric features and learning behaviors. This method provides educators with more choices and more effective tools to design and optimize their classroom layout. Machine vision technology can help designers understand user feelings and improve suggestions for products by analyzing user experience and feedback. For example, by using machine vision technology to record and analyze the process of users, it is possible to understand users' needs and pain points, thereby guiding product improvement and optimization. In addition, machine vision technology can also automate the analysis of user evaluations and feedback through emotional analysis and other means. For example, by analyzing and processing the texture, pattern, and other features on the surface of a product, cultural elements and artistic styles can be extracted, providing a more accurate and reliable basis for product design and evaluation [7].

CAD model optimization technology is a technology to optimize and improve the product model by using CAD software. By optimizing the details of the product model, the aesthetics and user experience of the product can be improved. By optimizing the product model structure, the practicability and durability of the product can be improved. By optimizing the product model process, the production efficiency of the product can be improved. The purpose of this article is to discuss how to analyze users' needs based on machine vision technology in Wenchuang product design and to improve product design quality and user experience by using CAD model optimization technology. In the product design of Wenchuang based on machine vision, the users' needs and expectations for products are understood by collecting and analyzing information such as users' behavior and expression. According to the results of the analysis, the product model is designed using CAD software. Feedback the optimized model to the user, observe the user's reaction, and make adjustments to achieve the best design effect. Compared with traditional research, this article has the following innovations:

(a) In traditional Wenchuang product design, user demand analysis mainly relies on manual observation and inquiry, making it difficult to achieve accuracy and objectivity. This article introduces machine vision technology to simulate human visual functions through computers and collect and analyze user behavior, facial expressions, and other information, which can more deeply explore user needs and preferences.

(b) This article combines CAD model optimization technology with machine vision technology and, based on user demand analysis results, performs detailed optimization, structural optimization, and process optimization operations on the product model, which can improve the design quality of the product.

(c) By introducing machine vision technology and CAD model optimization technology, this article can achieve automation and intelligence in the Wenchuang product design process. Designers can use computer software to optimize and improve product models automatically while using machine vision technology to analyze and identify user needs automatically, thereby improving design efficiency.

(d) Traditional Wenchuang product design mainly focuses on fields such as culture, art, and education. This article introduces machine vision technology and CAD model optimization technology into Wenchuang product design, expanding the design scope of Wenchuang products.

In this article, the utilization of machine vision in Wenchuang product design is thoroughly examined. Furthermore, the processes of user demand analysis and CAD model optimization are detailed. To validate the efficacy of the proposed approach, experimental verification was conducted. Ultimately, the findings of this research are summarized, and their significance and contribution to the field of Wenchuang product design are thoroughly analyzed.

2 RELATED WORK

With the rapid development of increasingly fierce market competition, the design and development cycles of products have become shorter and shorter, while the complexity of products continues to increase. To meet this requirement, Liu [8] explored the rapid design method and application of industrial products based on 3D CAD systems. 3D CAD systems. Through a 3D CAD system, designers can express design ideas more intuitively and accurately, conduct efficient model construction and modification, and conduct virtual product testing and evaluation. The rapid design of industrial products requires optimization of the design process. Designers need to clarify the functional requirements of the product and conduct conceptual design based on these requirements. In the conceptual design phase, designers can use 3D CAD systems to construct and modify models quickly. The rapid design of industrial products requires attention to standardization and modularization of design. Standardized design can greatly shorten the design cycle, while modular design can ensure product functionality while reducing design complexity. 3D CAD systems can assist designers in standardized design and modular construction, thereby improving design efficiency. Machine vision technology can achieve automated design and production through digital scanning and reconstruction of traditional bamboo woven cultural products. Designers can use CAD software to modify and optimize digital models generated by machine vision technology, improving product quality and production efficiency. At the same time, machine vision technology can also achieve rapid prototyping and production of products through rapid manufacturing technologies such as 3D printing, shortening the product development cycle. Lu et al. [9] explored how to use user review data-driven methods, combined with computer-aided design and computer graphics, to optimize the design of traditional bamboo weaving cultural products. By digitizing and reconstructing traditional bamboo weaving cultural products, designers can extract the characteristics and elements of bamboo weaving technology and integrate them into modern design. At the same time, machine vision technology can also extract features and styles from cultural elements such as historical relics and cultural heritage through digital reconstruction and processing. And integrate it into the design and development of traditional bamboo-woven cultural products. CAD model optimization technology can ensure more accurate and detailed design of cultural and creative products. For example, high-precision digital scanning and reconstruction through machine vision technology can obtain the precise form and details of the product, avoiding possible errors and deficiencies in manual production. In addition, CAD model optimization technology can also optimize the structural design of products, improving their stability and durability. Mulero et al. [10] used CAD model optimization techniques to better simulate the actual effects of cultural and creative products, including appearance, dimensions, materials, etc. This simulation can more realistically demonstrate the effectiveness of the product in actual use, allowing users to have a more intuitive understanding of the characteristics and usage methods of cultural and creative products. This enhancement of realism can enhance users' trust and satisfaction with the product, thereby improving the user experience. Meanwhile, using machine vision technology for user demand analysis and market trend analysis can provide more precise strategic guidance for the design of cultural and creative products, meeting market demands and user expectations. These factors can make cultural and creative products more competitive in the market.

The 3D factory simulation software based on machine vision has significant applicability in computer-aided participatory design of traditional cultural and technological venues. This software can provide a digital environment where designers can create, edit, analyze, and visualize 3D models to simulate and optimize traditional cultural crafts. Through 3D factory simulation software, Pellicia et al. [11] more accurately simulated the appearance, size, and material of cultural and creative products, thereby improving the design quality and user experience of the products. At the same time, this software can also optimize the structure of the product and improve its stability and durability. 3D factories help designers better understand the manufacturing and production processes of products and improve their manufacturability and production efficiency. This simulation can also help designers detect and solve problems early on, reducing errors and waste in production. Convolutional neural network-based techniques can analyze and learn from a large amount of user data. This technology can automatically identify and extract users' preferences and needs for cultural and creative products. Its model optimization mainly involves automated processing and analysis of existing CAD models through deep learning algorithms to improve the design quality and production efficiency of cultural and creative products. Płosza et al. [12] used deep learning algorithms to optimize and reconstruct CAD models, which can improve the structural stability and manufacturability of products, as well as shorten the R&D and production cycles of products. By parameterizing CAD models through deep learning algorithms, the shape, size, and other features of the model can be transformed into adjustable parameters, making it easier for designers to design and adjust more flexibly.

With the rapid development of technology, augmented reality (AR) technology has been widely applied in many fields. In the manufacturing industry, AR technology has brought new solutions for equipment maintenance. Runji et al. [13] explored how to use AR technology for user demand analysis of equipment maintenance in the manufacturing industry, as well as the importance of engineering computing and information science in this process. AR technology can combine digital information with the real world, enabling users to perform virtual operations in the real environment. In the maintenance of manufacturing equipment, AR technology can help users carry out more efficient and convenient maintenance work. For example, through AR glasses or head-worn displays, users can obtain real-time information about the device, such as operating status, fault warnings, etc. AR technology can also provide 3D models and operation guidelines, allowing users to conduct equipment maintenance more intuitively. In the manufacturing industry, augmented reality-based equipment maintenance provides users with new solutions. To better apply AR technology, understanding and analyzing user needs is crucial. At the same time, engineering computing and information science play an important role in this process. By combining engineering computing with information science methods and tools, we can further improve the efficiency and effectiveness of AR equipment in manufacturing equipment maintenance. This will help improve the production efficiency and quality of the manufacturing industry and promote its sustainable development. Soori and Asmael [14] simulated and optimized traditional process flow through computer-aided process planning. When making traditional ceramic products, CAD models are used to simulate the design and manufacturing process, optimize the mold structure and manufacturing process, and improve production efficiency and product quality. Computer-assisted process planning provides designers with a more accurate and reliable design basis through the analysis and processing of a large amount of process data. For example, when making traditional textiles, Computer Aided Process Planning

(CAPP) can be used to analyze and design data on the texture, texture, and color of textiles, to provide more accurate design solutions. When making traditional wooden products, CAPP can be used to optimize the cutting, splicing, and polishing processes of wood to improve the utilization rate and production efficiency of wood. Machine learning has a wide range of applications in the generative design preferences of traditional cultural products. By learning historical data and user feedback, machine learning can help designers better understand user needs and preferences, thereby creating cultural products that are more in line with user preferences. Sun et al. [15] predicted future market trends and potential user needs by studying historical market data and user behavior data, thereby providing designers with more accurate design directions and suggestions. For example, if machine learning algorithms predict that people in a certain region will prefer to purchase products with a certain style in the future, designers can design in advance based on this data to better meet the needs of users. The process of product development is undergoing revolutionary changes. Human-centered product development emphasizes the core position of user needs, preferences, and behaviors in product design and development. Generation algorithms, which can automatically generate algorithms that meet specific conditions or requirements, are widely used in human-centered product development. Urquhart et al. [16] explored the application of generation algorithms in human-centered product development. Generative algorithms have extensive applications in fields such as machine learning, optimization problem solving, and bioinformatics. These algorithms can automatically generate solutions that meet specific conditions or requirements based on existing data. In human-centered product development, generation algorithms can be used to understand user needs, predict user behavior, optimize product design, and more. Human-centered product development emphasizes the importance of user needs and behaviors in product development. By using generation algorithms, developers can better understand user needs, predict user behavior, and design products that better meet user needs. In addition, generation algorithms can also help optimize product design and improve product performance and user experience. Car manufacturers can use generation algorithms to automatically generate car design solutions based on user needs and preferences, improving product performance and user experience. By analyzing user browsing history, purchase records, and other data, personalized product recommendation schemes can be automatically generated using generation algorithms. Emotional product design has become an important direction in the field of industrial design. Emotional product design aims to endow products with more emotional value by understanding users' needs and emotional reactions, to improve users' user experience and satisfaction. Wang et al. [17] explored the multi-objective emotional product design of data-driven 3D modeling and color fusion to achieve more personalized and differentiated products. 3D modeling design is an important component of emotional product design. Different colors can trigger different emotional reactions. Therefore, the selection of colors has a crucial impact on the emotional value of a product. To verify the effectiveness of multi-objective emotional product design driven by data-driven 3D modeling and color fusion, we conducted a case study. We have designed a smart water cup that can detect users' drinking water volume and changes through sensors and remind users to drink water through a mobile app. In the design, we used data-driven methods to design the three-dimensional shape and color selection of the water cup based on the user's drinking water volume and changes in drinking water volume. At the same time, we have considered multiple objectives, including user needs, product functionality, usage environment, etc., to achieve the best emotional effect of the product.

Oil paper bamboo umbrella is a traditional handicraft that is deeply loved by people for its unique texture, color, and shape. Through deep learning technology, we can extract image features of different styles from a large number of oil paper and bamboo umbrella images, such as color matching, texture style, shape design, etc. These features can form a "style dictionary" to guide. Wu and Zhang [18] explored how to apply deep learning to image style recognition and intelligent design of oil paper bamboo umbrellas, further promoting the development of computer-aided design and application. Deep learning is a machine learning technology in the field of artificial intelligence that can simulate the working mode of human brain neural networks, thereby efficiently processing and recognizing complex data such as images and sounds. In terms of image style recognition, deep learning technology can be applied to the learning and analysis of a large number of oil paper and bamboo umbrella images, thereby identifying image features of different styles. In the design and manufacturing process of oil-paper bamboo umbrellas, deep learning technology is used to achieve image style recognition and intelligent design, which not only improves product quality and aesthetics but also provides traditional handicraft industries. In addition, the introduction of deep learning technology can also promote the development of cross-disciplinary cooperation, such as applying the image style recognition of oil paper and bamboo umbrellas to product design in other fields, thereby creating more innovative design works. Xu and Zheng [19] discussed how to use computer perception image systems to evaluate cultural and creative product design, and combined them with relevant technologies of computer-aided design to explore. Firstly, it is necessary to understand the application of computer perception image systems in the design and evaluation of cultural and creative products. Computer perception image systems can collect and analyze product images, videos, and other data, extract product features and attributes, and objectively evaluate the product. Computer perception image systems can be used to evaluate the appearance, structure, color, and other aspects of the product. Computer-aided design software can assist designers in efficient modeling and rendering [20].

3 USER REQUIREMENT ANALYSIS

3.1 Importance of User Demand Analysis

Machine vision technology is a technology that utilizes computers to simulate human visual functions. It can achieve recognition, measurement, tracking, and other functions of target objects by analyzing and processing images and videos. In Wenchuang product design, machine vision technology is mainly applied to user demand analysis and product model optimization. Machine vision can objectively and accurately analyze and process a large amount of image and video data to extract the features and attributes of the target object, avoiding the interference of human subjective factors. Moreover, this technology can utilize the high-speed processing capability and automation technology of computers to analyze and process a large amount of data quickly and automatically. Machine vision technology can obtain reproducible results by repeatedly analyzing the same batch of data, facilitating data expansion and model optimization.

By collecting and analyzing information such as user behavior and facial expressions, machine vision technology can deeply explore user needs and preferences, providing a basis for personalized product design. FDesigners can leverage machine vision technology to facilitate the recognition and analysis of users' facial expressions, thereby gaining insights into their preferences and feedback on products. This information can then be utilized to refine and optimize the product design. Additionally, machine vision technology enables designers to identify and quantify the intricacies of product models automatically. By optimizing and refining these details based on the obtained measurements, designers can enhance the product's aesthetics and overall user experience. Machine vision technology can be used for the creation and assessment of artistic works. For example, by extracting and analyzing features from images of artworks, the artistic value and style characteristics of the works can be evaluated. Moreover, machine vision technology can also be used to automate the creation of artistic works, improving the efficiency and quality of artists' creations. User requirement analysis is a crucial part of Wenchuang product design. It not only relates to the design direction and target market positioning of the product but also directly affects the practicality and user experience of the product. User demand analysis is the process of conducting research and analysis on factors such as the market, users, and competitors to understand users' needs and expectations for products, thereby providing a basis for designers to design products that better meet user needs. It is very important to understand user behavior, facial expressions, feedback, and other information in user demand analysis. This information can reflect users' interests, needs, and preferences, helping designers gain a deeper understanding of users' psychological and behavioral characteristics and providing a basis for personalized product design.

By analyzing competitive products in the market, one can understand the advantages, disadvantages, market share, and other information of similar products, thereby providing ideas for differentiated design of products. By analyzing market trends, we can predict future market demand and changes, providing direction for product upgrades and long-term development. User demand analysis can help designers gain a deeper understanding of user needs and expectations, providing a basis for personalized product design; Moreover, it can also help designers better understand market demands and trends, providing direction for product upgrades and long-term development.

3.2 Using Machine Vision Technology to Collect User Data

In Wenchuang product design, the use of machine vision technology can effectively collect user data and provide designers with more comprehensive and accurate design references. Machine vision technology can collect and analyze user behavior, facial expressions, and other information, deeply explore user needs and preferences, and provide a basis for personalized product design. By utilizing facial recognition technology and other devices, it is possible to collect the facial expressions of users during the use of the product, including their emotions and emotions. This information can help designers gain a deeper understanding of users' emotional experience and satisfaction with the product, thereby enabling emotional design and optimization of the product. By utilizing devices such as limb recognition technology, it is possible to collect information such as body language and gestures from users during the use of the product, thereby helping designers better understand users' needs and intentions. The user emotion recognition model based on machine vision is shown in Figure 1.

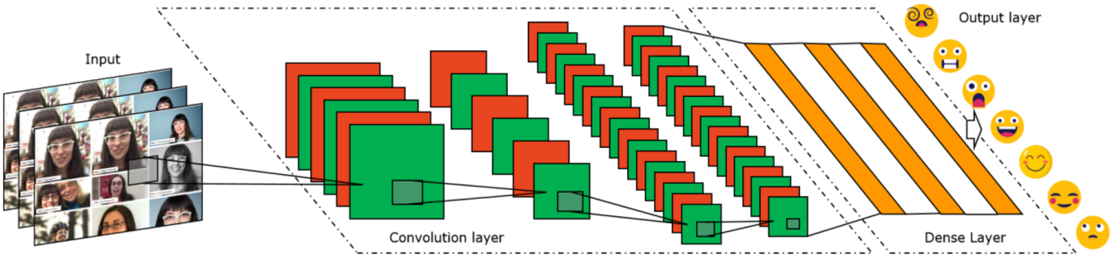


Figure 1: User sentiment recognition model.

Calculate the similarity between Wenchuang products:

$$sim(i,j)=\frac{\vec{i}\cdot\vec{j}}{\|i\|\|j\|} \tag{1}$$

Calculate the correlation between two vectors:

$$sim(i,j)=\frac{\sum_{u\in U}(R_{u,i}-\bar{R}_i)(R_{u,j}-\bar{R}_j)}{\sqrt{\sum_{u\in U}(R_{u,i}-\bar{R}_i)^2}\sqrt{\sum_{k\in R_{mn}}(R_{u,j}-\bar{R}_j)^2}} \tag{2}$$

$$sim(i,j)=\frac{\sum_{u\in U}(R_{u,i}-\bar{R}_u)(R_{u,j}-\bar{R}_u)}{\sqrt{\sum_{u\in U}(R_{u,i}-\bar{R}_u)^2}\sqrt{\sum_{k\in R_{mn}}(R_{u,j}-\bar{R}_u)^2}} \tag{3}$$

$\bar{R}_u$ is the average value of users' ratings for all Wenchuang products, and $R_{u,i}$ represents users' u ratings for Wenchuang products i.

By segmenting the collected user data, the user group is divided into different subgroups. Then, analyze the user needs of each segmented group better to understand the needs and preferences of different groups. By analyzing user feedback information, we can understand user satisfaction and improvement suggestions for the product. For example, it is possible to analyze users' textual descriptions, ratings, comments, and other information when evaluating products, to understand their feelings and needs for the product. Display and analyze the collected user data through data visualization, such as creating charts and data reports. Data visualization can help you better understand user needs and feedback, and facilitate communication and communication with other team members.

3.3 Design Optimization Based on User Needs

Design optimization based on user needs can help designers understand user needs and preferences, thereby providing a basis for personalized product design. By conducting in-depth analysis of user behavior data, understand the user's usage of the product and provide feedback. Analyze the emotional changes of users during the use of the product, including their emotions and emotions. This information can help designers gain a deeper understanding of user needs and intentions, providing a basis for emotional design and optimization of products. By analyzing user feedback information, understand user satisfaction with the product and improvement suggestions. Integrating user usage scenarios, behavioral habits, emotional changes, and other information into a complete storyline helps designers better understand user emotions and needs, providing a more comprehensive and accurate basis for product design. The emotional tendency of characteristic words is:

$$tendency = \frac{1}{n}\sum_{i=1}^{n} sim\ word, seed_{1i} \ - \frac{1}{m}\sum_{i=1}^{n} sim\ word, seed_{2j} \tag{4}$$

It is found that when $a_i \neq 0$, the corresponding vector X_i is the support vector. Therefore, the decision function is rewritten as:

$$f\ x\ = \operatorname{sgn}\left(\sum_{i=1}^{M} a_i y_i K\ x, x_i\ + b\right) \tag{5}$$

Where M represents the number of support vectors.

The similarity calculation between concepts will be transformed into the similarity calculation between sememes:

$$Sim\ p_1, p_2\ = \frac{a}{d+a} \tag{6}$$

Where p_1 is the original meaning 1; p_2 is the original meaning 2; d is the path length of p_1, p_2 in the semantic tree system; a is an adjustable parameter.

Design optimization based on user needs requires designers to deeply understand user needs and preferences, flexibly use different design methods and tools, and provide a basis for personalized product design. Moreover, practical design attempts and verifications are also needed to improve the design quality and user experience of the product by repeatedly modifying and optimizing the design scheme.

4 CAD MODEL OPTIMIZATION

4.1 The Meaning and Purpose of Cad Model Optimization

CAD model optimization denotes the procedure of refining and enhancing product models through the use of CAD software. Its primary objective is to enhance the design quality and user experience of products, thereby augmenting the market competitiveness of Wenchuang products. During the CAD model optimization process, designers can leverage computer software to refine and enhance product models automatically. Additionally, they can employ machine vision technology to facilitate automatic analysis and identification of user requirements. Model detail optimization entails refining the finer aspects of a product model, such as edge smoothing and surface texture mapping, to elevate the aesthetics and user experience of the product. Structural optimization involves the rational design of a product's internal structure to bolster its stability, durability, and safety. Process optimization refers to the enhancement and streamlining of the model production process to improve production efficiency and product quality. By optimizing CAD models, the design quality and user experience of products are elevated, thus bolstering the market competitiveness of Wenchuang products.

4.2 Optimizing CAD Models Using Machine Vision Technology

Through machine vision technology, designers can achieve automatic recognition, measurement, and tracking of product models, providing more accurate and objective data support for model optimization. The algorithm implementation of CAD model optimization using machine vision technology mainly includes the following steps:

㊀ Image acquisition: Firstly, image acquisition is required for the product model, which can be done using high-precision cameras or scanning equipment.

㊁ Image preprocessing: Preprocessing the collected images, such as denoising, enhancement, segmentation, etc., to improve image quality and recognition accuracy.

㊂ Feature extraction: By extracting features from images, the shape, size, texture, and other feature information of the product model are extracted.

④ Model matching: Match the extracted feature information with existing CAD models to find the model with the highest similarity.

⑤ Model optimization: Based on the matching results, improve the CAD model with the highest similarity, such as adjusting dimensions, changing shapes, etc.

⑥ Optimization assessment: Evaluate and validate the optimized model to ensure that it meets design requirements and practical application needs.

The algorithm framework for CAD model optimization mainly includes several steps: Wenchuang product image input, depth map sampling, multi-view sampling point fusion, and 3D model extraction. Firstly, it is necessary to capture images of the Wenchuang product through a camera or scanning device and input the collected images into the algorithm framework. Then, computer vision algorithms are used to sample the depth map of the input image, that is, by sampling and estimating the depth information of the image, the 3D shape of the Wenchuang product is obtained. Multi-view sampling point fusion is performed on the 3D morphology obtained from depth map sampling, which involves fusing sampling points from different perspectives to obtain a more accurate 3D model. By performing surface reconstruction, texture mapping, and other operations on the 3D model obtained by fusing multiple view sampling points, the 3D model of the Wenchuang product is extracted. Based on user needs and designer creativity, perform detailed optimization, structural optimization, and process optimization on the extracted 3D model to improve the design quality and user experience of the product. The algorithm framework for CAD model optimization is shown in Figure 2.

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R & T \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \tag{7}$$

Orthographic plane V :

$$x' = x_0 - x; z' = y - y_0 \tag{8}$$

Side projection plane W :

$$y' = x - x_0; z' = y - y_0 \tag{9}$$

Horizontal projection plane H :

$$x' = x_0 - x; y' = y_0 - y \tag{10}$$

$o' = x_0, y_0$ is the coordinate origin of the projection plane coordinate system.

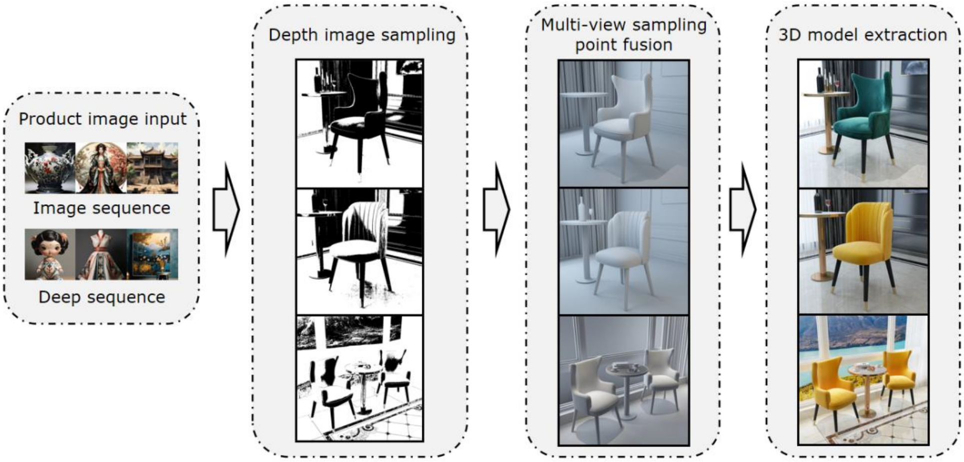


Figure 2: Algorithm framework of CAD model optimization.

5 CASE ANALYSIS OF USER DEMAND ANALYSIS AND CAD MODEL OPTIMIZATION

In the experiment, a set of raw data of Wenchuang products, including different types of products such as ceramics and wood carvings, was first collected. By comparing with the original model, observe the degree of restoration of the reconstructed model in terms of details and shape. After model reconstruction, use some existing user requirement analysis methods to conduct requirement analysis on the product, and optimize the CAD model based on the analysis results. This mainly includes optimization and improvement of product structure, materials, processes, and other aspects.

5.1 Mining and Analysis of User Needs

In the task of analyzing users' needs, the algorithm in this article collects and analyzes users' behaviors, expressions, and other information by introducing machine vision technology, to deeply explore users' needs and preferences and provide a basis for personalized design of products. Figures 3 and 4 show the performance of the accuracy and recall of the algorithm in the task of user demand analysis. The algorithm shows high accuracy and recall in the task of user demand analysis.

The algorithm in this article adopts efficient image processing and feature extraction methods in collecting information such as user behavior and facial expressions. Through in-depth analysis and processing of image and video data, feature vectors reflecting user needs and preferences are extracted. Through technologies such as data fusion and knowledge transfer, information from different data sources is organically integrated, improving the accuracy and recall of predictions. Through accurate requirements analysis results, it is possible to better understand user needs and expectations, provide clear directions and suggestions for CAD model optimization, and also provide support and guidance for the selection and application of optimization technologies.

5.2 Effect Assessment After Optimization of Cad Model

Even with the help of CAD software, there may still be some problems in the product design model, such as invalid triangular patches and independent triangular mesh blocks. The existence of these issues may lead to a decrease in the accuracy of the product model, and in some cases, may even affect the manufacturing and performance of the product.

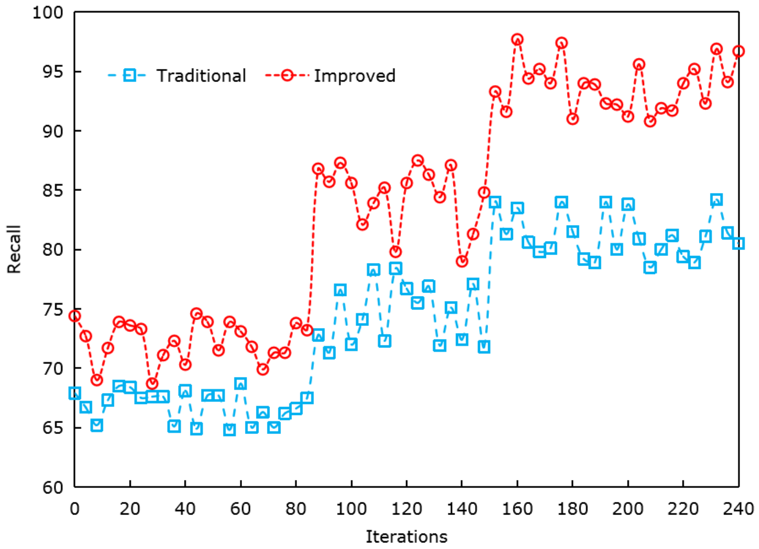


Figure 3: Accuracy of user emotion calculation.

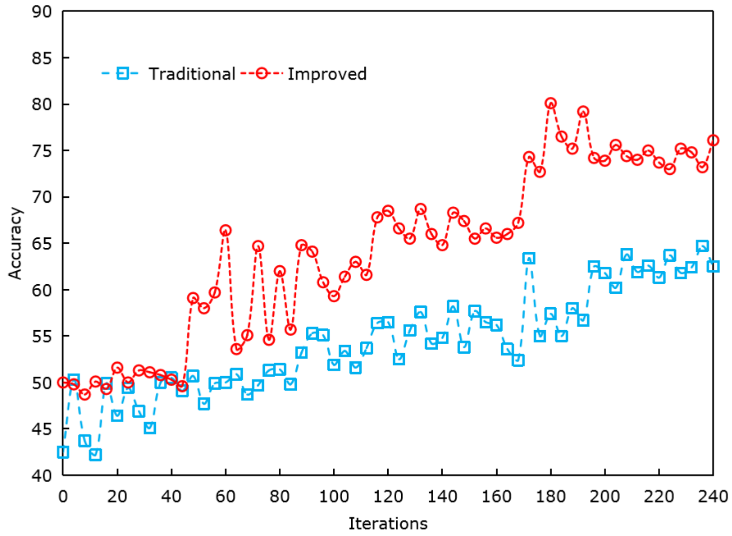
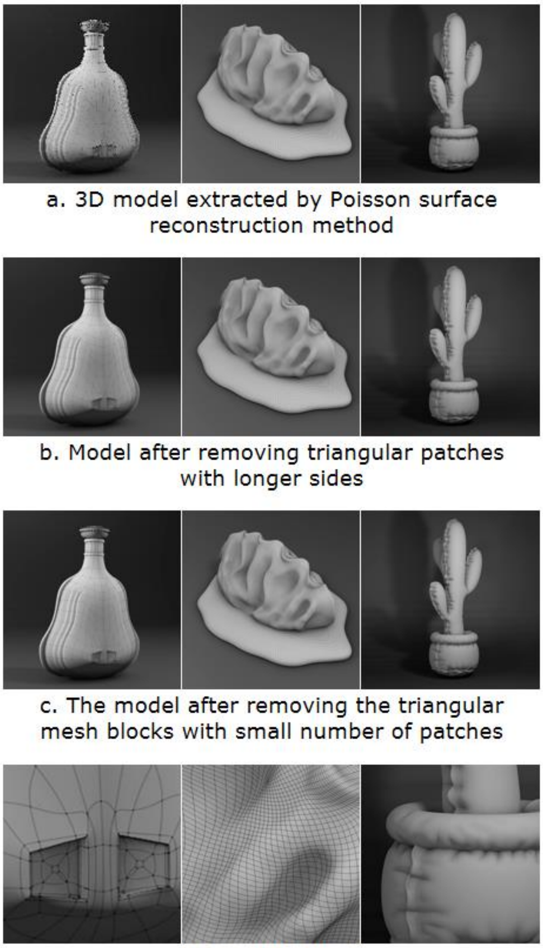


Figure 4: Recall of user emotion calculation.

Figure 5a shows a grid model of a product model generated by CAD software. This mesh model is a closed structure, meaning that it has no open boundaries, and all faces are connected to other faces. However, this model contains many invalid triangular patches. These invalid triangular patches may be caused by improperly connected vertices, incorrect surface partitioning, or redundant details during the modeling process. Figure 5b shows that after some operations, the mesh model still contains some independent triangular mesh blocks. These independent triangular mesh blocks may be due to over-emphasizing the details of certain parts during the modeling process, or some parts not being correctly merged when connected. To address these issues, some elimination operations are required. In this process, it is necessary to first identify and delete invalid triangular patches. Then, for those independent triangular mesh blocks that still exist, if their quantity of patches is less than 10000, they also need to be removed. After the above processing, a complete product model as shown in Figure 5c was obtained.



a. 3D model extracted by Poisson surface reconstruction method

b. Model after removing triangular patches with longer sides

c. The model after removing the triangular mesh blocks with small number of patches

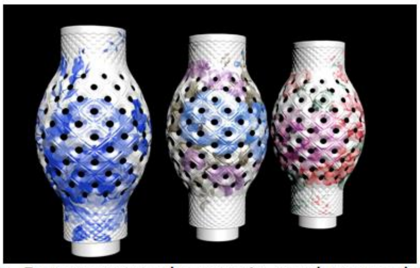
d. Local features

Figure 5: Schematic diagram of 3D geometric model extraction.

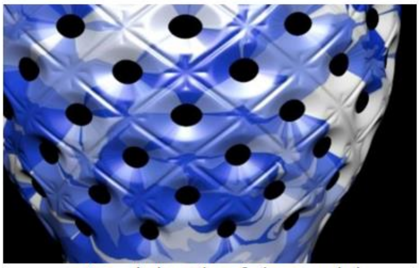
Figure 6 shows a modeling example of a set of Wenchuang products. The time required for sampling and fusion of all instance point clouds and the final quantity of generated point clouds is shown in Table 1, with a resolution of 1280 for all instances × 720. From the reconstruction results in Figure 6b, it can be seen that the method proposed in this article can completely reconstruct the overall structure of ceramic products, showcasing their overall morphology and characteristics. This completeness not only reflects the effectiveness of the algorithm but also indicates that the method can accurately capture the overall information of the product. From the reconstruction results in Figure 6c, it can be seen that due to the use of a deep non-uniform sampling method, the algorithm can maintain sufficient sampling rates in areas with rich depth features. In the local details of the product structure, the algorithm can perform more accurate reconstruction. Designers can draw inspiration from these details for more refined design and optimization.

Figure 7 shows an example of a group of woodcarving products with complex structures and "self-occluding" parts. In the presence of "self-occluded" parts, traditional modeling methods often find it difficult to accurately reconstruct these occluded parts. The method presented in this article has shown good results in addressing these issues. The method presented in this article demonstrates excellent performance in both reconstructing the overall structure of woodcarving products and restoring local details of the products. For example, for the "self-occluding" parts in wood carving products, this method can accurately reconstruct the shape and details of these parts, so that the reconstructed model remains highly consistent with the original model in terms of details.

a. Input image sequence and depth map



b. Reconstructed ceramic product model

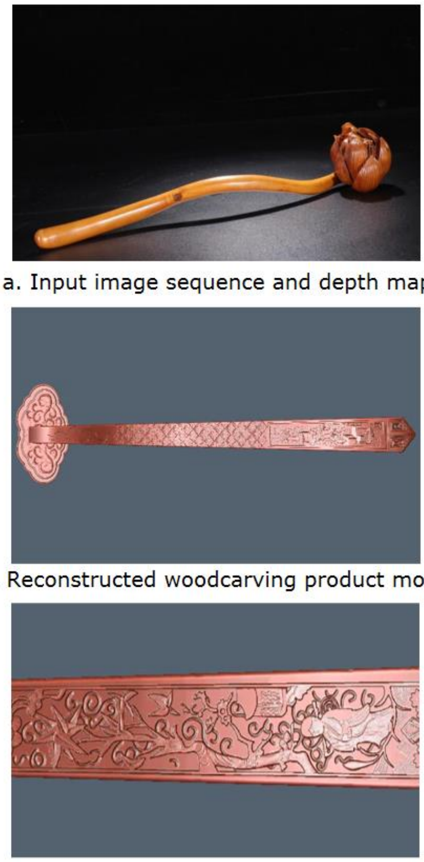


c. Local details of the model

Figure 6: 3D reconstruction results of ceramic products.

Example	*Frame number*	*Sampling and fusion time/min*	*10-4×Number of generated point clouds/piece*
Glass products	525	28	11.28
Traditional clothing	421	16	14.35
Ceramic products	295	15	29.07
Woodcarving products	331	17	37.38

Table 1: Time-consuming sampling and fusion and the quantity of generated point clouds in this article.



a. Input image sequence and depth map

b. Reconstructed woodcarving product model

c. Local details of the model

Figure 7: 3D reconstruction results of woodcarving products.

This method can keep enough sampling rate in the area with rich depth features so that the reconstruction algorithm can better capture and reconstruct the local details of the product. In addition, this method effectively deals with the "self-occlusion" local structure by adjusting the sampling rate reasonably and avoids the problem of inaccurate model reconstruction caused by insufficient sampling.

6 SUMMARY AND OUTLOOK

This article aims to explore how to conduct user demand analysis based on machine vision technology in Wenchuang product design and utilize CAD model optimization technology to improve product design quality and user experience. The results show that the method proposed in this article has high accuracy and recall in user demand analysis and CAD model optimization, and can effectively support personalized design and optimization of products. Moreover, this method can effectively handle the "self-occlusion" local structures present in the product, accurately reconstructing the shape and details of these parts. Due to the use of deep non-uniform sampling methods, the algorithm can maintain sufficient sampling rates in areas with rich depth features. In the local details of the product structure, the algorithm can perform more accurate reconstruction. This study provides an effective solution for the modeling and design of Wenchuang products. In the future, algorithm performance will be further optimized to improve reconstruction speed and accuracy, to better support the design and manufacturing of Wenchuang products.

7 ACKNOWLEDGEMENT

This work was supported by the Hubei Association of Higher Education: Research on the construction and application of Virtual Simulation Experiment Course of Hubei intangible cultural heritage creative product design under the background of digital empowerment, 2023XC075.

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