Structural Analysis and Design Optimization of Ceramic Products Based on 3D Scene Simplification Algorithm

Chuanbao Niu[1] and Zhuoyue Diao[2]

[1]Institute of Art Media, Hefei Normal University, Hefei 230601, China,
niuchuanbao@hfnu.edu.cn
[2]School of Design, Shanghai Jiao Tong University, Shanghai 200240, China,
diaozhuoyue@sjtu.edu.cn

Corresponding author: Chuanbao Niu, niuchuanbao@hfnu.edu.cn

Abstract. In today's information context, it has become the mainstream way of life to recognize and interact with things by means of information, and the ceramic industry is no exception, which has developed from the traditional manual way to the high-tech auxiliary way. In order to promote the use of computer aided design (CAD) technology in ceramic design and assist the structural analysis and design optimization of ceramic products, this article proposes a 3D scene simplification algorithm of virtual reality (VR) based on photon mapping algorithm. The test and analysis of the algorithm show that the algorithm can be applied to the simplification of 3D model of ceramic design and some real-time interactive systems. With the support of VR, ceramic products can be browsed in all directions, scenes can be roamed and information can be exchanged. This not only provides convenience for the structural analysis and design of ceramic products, but also avoids the drawback that the traditional physical display method is not harmonious with the vulnerability characteristics of ceramic products.

Keywords: CAD; Virtual Reality; Ceramic Design; Structural Analysis
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1 INTRODUCTION

Design is the soul of ceramic products, and CAD is the tool of soul performance. The combination of CAD and ceramic product design expands a new space for ceramic product design, and enables the culture in the field of traditional ceramic products to be used and developed more quickly. The potential of virtual reality in the early design stage is mainly reflected in its two-way attention to product functionality and emotional dimensions. This focus not only involves the actual functionality of the product, but also involves the emotional experience of users. The specific matching between virtual reality technology and design functions is highly personalized, which is reflected in the fact that different design tasks may require different virtual reality technologies to support. However, this matching does not have a clear separation, as virtual reality technology has always existed to support design tasks. Berni and Borgianni [1] use virtual reality technology to simulate product usage. This not only improves the functional quality of the product, but also optimizes the user experience, making it more comfortable and enjoyable. The potential of virtual reality in the early design stage is mainly reflected in its focus on product functionality and emotional dimensions, as well as personalized support for design tasks. Although it cannot be claimed that there is a clear separation between virtual reality devices and supported design tasks, the correlation matching between them has been personalized to meet different design needs. With the growth of CAD and its wide use in the field of product design, the efficiency and quality of product design have been greatly improved, and the production cost increase and production design development cycle have been reduced, which has had an important impact in many fields such as industrial production, machinery manufacturing, creative expression, engineering design and scientific research. In the manufacturing industry, industrial robots are widely used in various production processes, such as assembly, welding, transportation, etc. In order to achieve automated programming of industrial robots, many researchers and enterprises have conducted extensive explorations. For example, some researchers use model-based methods to program by establishing robot kinematic models and target task models. In addition, some researchers use machine learning technology to generate programming code for robots by learning a large amount of data. However, these methods still have some problems, such as low programming efficiency and high skill requirements for programmers. With the continuous development of industrial automation, robot programming has become a key link in the production process. Traditional programming methods require a lot of time and resources, and require high skills and experience from programmers. However, the application of ceramic product design cannot blindly pursue technology and innovation, while ignoring the cultural connotation, national characteristics and aesthetic value of ceramic products. Therefore, the application of CAD in ceramic product design should combine digital technology with artistic aesthetics in order to give full play to the application advantages of CAD in ceramic product design. The product design of virtual ceramics is mainly to build a 3D model of ceramic products through new technologies, so as to facilitate customers to browse the product information intuitively.

The projection moire measurement method is a non-contact, high-precision three-dimensional measurement technology widely used in reverse engineering, biomedical, visual inspection and other fields. However, this method still faces some challenges in measuring complex surfaces, such as data collection speed and accuracy issues. To address these issues, Cai et al. [2] proposed a high-precision projection moire measurement method based on virtual reality bridging. In the field of moire measurement, researchers have proposed many methods to improve measurement accuracy and speed. For example, some methods use high-speed cameras and special light sources to obtain more texture information, while others use machine learning algorithms to optimize measurement results. However, these methods still cannot meet the requirements of certain application scenarios. Photon detection can increase the sensitivity of imaging, thereby improving the signal-to-noise ratio of the image; Secondly, photon statistical distribution can reflect the structural information of images, which is helpful for the extraction and recognition of image features. Dodda et al. [3] used photon detectors to detect incoming photons and counted the number and distribution of photons at each pixel point. Based on photon statistical results, estimate the noise level in the image, including the type, intensity, and distribution of noise. Based on the noise estimation results, appropriate methods are used to remove noise from the image, such as filtering, reconstruction, etc. In the automotive industry, the handling and presentation of lighting has always been an important challenge for designers and engineers. With the continuous development of technology, game engines and virtual reality (VR) provide new possibilities, allowing designers to present their designs in a more intuitive and vivid way. A game engine is a software system used to create and manage games and highly interactive virtual environments. They typically incorporate real-time rendering technology, as well as powerful physics engines and artificial intelligence capabilities, to create scenes with complex visual effects and user experiences. Virtual reality (VR) is a computer technology that creates a realistic, immersive virtual environment by simulating human auditory and visual perception. In automotive design, VR technology is mainly used in the early design stage to verify the feasibility and human-machine interaction of the design. Ekstrmer et al. [4] applied game engines and VR technology to automotive lighting design. This can provide an immersive and interactive display environment. Designers can simulate various actual lighting conditions in a virtual environment, such as different weather, time, road, and vehicle speeds, to evaluate the performance and design effectiveness of lighting systems. The era of computer as a tool has entered a mature stage, and it has influenced all technical fields of art design, even in the traditional, technological and practical field of ceramic product design, which has been widely used. The key to the success of new product development lies in obtaining market information accurately and quickly, developing products that users need and shortening the development cycle of new products to the maximum extent, rather than just designing and decorating behind closed doors. With the use of VR, the 3D CAD design of ceramic products can be effectively realized, and the ceramic products can be presented in a 3D form. With the growth of computer graphics, a real virtual environment for ceramic design can be established by traditional geometric methods. Usually, a 3D geometric model is created to describe the lighting and surface texture in the scene. It requires high computing power to generate the image of viewpoint observation by calculating the light intensity, and the resulting effect is difficult to reproduce the complex natural texture presented in the photo. Virtual display of ceramic products can not only obtain accurate and diversified user information, but also avoid the long cycle caused by the complicated specific stage of ceramic product development and the fragility of ceramics in the traditional physical display method. The combination of CAD and VR provides a new idea for structural analysis and design optimization of ceramic products.

Molecular product process design is a complex system engineering that involves multiple chemical reactions and process conditions. In each process, there is uncertainty in properties, such as the uncertainty of chemical reactions and process conditions. These uncertainties can lead to incomplete prediction and control of product properties, thereby affecting product quality and production efficiency. This uncertainty mainly comes from the uncertainty of chemical reactions and process conditions. These uncertainties may lead to incomplete prediction and control of product properties, thereby affecting product quality and production efficiency. To address this issue, Frutiger et al. [5] proposed a Monte Carlo based optimization strategy aimed at reducing the impact of property uncertainty on molecular product process design, improving product quality and production efficiency. To verify the effectiveness of the Monte Carlo based optimization strategy, an actual molecular product process design was used as an example. This process involves multiple chemical reactions and process conditions, such as reaction temperature, reaction time, catalyst concentration, etc. The distribution of product properties under different combinations of chemical reactions and process conditions was predicted through Monte Carlo simulation. Virtual design means that designers design a virtual product to analyze, study and check whether the designed product meets the design requirements and how to modify it when there are problems. In the analysis and inspection of virtual products, if problems are found, the design will be modified to make the product design more perfect and avoid making a model or sample before production. The organic combination of VR and ceramic product CAD design will guarantee the improvement of ceramic product design quality. Simplifying the 3D complex model is one of the key factors that affect the whole VR system, that is, simplifying the model as much as possible without affecting the graphic accuracy, deleting the vertices and faces in the model, so that it can be displayed in real time at high speed without distortion. In order to obtain ideal visual effect and computer processing speed, certain technology can be used to manage the models in the scene. In order to promote the use of CAD in ceramic design and assist the structural analysis and design optimization of ceramic products, this article proposes a VR 3D scene simplification algorithm based on photon mapping algorithm. The research innovations are as follows:

(1) This article proposes a VR 3D scene simplification algorithm for ceramic products, which can reduce the complexity of the scene while maintaining the key features and structure of the product, thus meeting the display requirements of ceramic products in VR environment.

(2) The interactive design function of ceramic products is realized in CAD tools, and users can modify and adjust ceramic products in real time through VR, thus improving the design efficiency and quality.

The structure of the section is as follows:

Section 1: Introduce the importance and application prospect of CAD and VR in structural analysis and design optimization of ceramic products.

Section II: Introduce the principles, characteristics and applications of CAD and VR in ceramic product design.

Section III: Introduce the concrete scheme of structural analysis and design optimization of ceramic products based on VR and CAD. Including VR 3D scene simplification algorithm, VR display technology and interactive design in CAD software.

Section IV: The effectiveness and superiority of the structural analysis and design optimization scheme of ceramic products based on VR and CAD are verified by experiments.

Section V: Summarize the main achievements and advantages of structural analysis and design optimization scheme of ceramic products based on VR and CAD, and put forward the direction and challenges of further research.

2 OVERVIEW OF RELATED TECHNOLOGIES

In modern society, the interior design and decoration of office buildings have become an important field. Due to the significant impact of the office environment on work efficiency and employee comfort, designers need to fully consider factors such as aesthetics, comfort, and environmental protection while meeting functional requirements. Virtual reality technology can provide designers and owners with a new way of design and decision support, helping them to fully consider various factors in the early stages of design, thereby avoiding design changes and rework in the later stages. Juan et al. [6] used a decision support model based on virtual reality for interior design and decoration. Firstly, we can use 3D scanning technology to scan and convert actual scenes into virtual environments. Then, we can add different furniture and furnishings in the virtual environment for designers to match and choose from. Through interactive design, designers can freely explore, design, and modify in a virtual environment. In today's industrial design field, 3D CAD systems have become mainstream tools that can significantly improve the quality and efficiency of product design. Liu [7] introduced a rapid industrial product design method based on 3D CAD systems and explored its advantages in practical applications. In rapid industrial product design, 3D CAD systems play a crucial role. This system provides powerful modeling capabilities through computer-aided design technology, enabling designers to quickly create and modify product designs. Among them, the integration of reverse engineering, finite element analysis and other technologies further improves the quality and efficiency of product design. Reverse engineering is a method of obtaining design information from existing products or models, which allows designers to innovate designs based on existing products. Finite element analysis is a calculation method used to evaluate the mechanical properties of a product, such as strength, stiffness, and fatigue life, to ensure that the product design meets the requirements.

Through VR technology, designers can simulate the usage of products in the early stages of product design, in order to predict and solve potential problems. Lorusso et al. [8] utilized VR and AR technologies to jointly create and modify product designs in a shared virtual environment to improve design efficiency and accuracy. With the rapid development and popularization of 5G networks, more and more devices and scenarios are starting to connect to 5G networks, enjoying the benefits of high speed, low latency, and Dalian connectivity brought by 5G networks. In this context, it has become possible to implement a distributed immersive augmented reality (AR) architecture. The distributed AR architecture can seamlessly integrate virtual information with the real environment, providing users with an immersive experience. At the same time, utilizing the characteristics of 5G networks, it can further enhance user experience and expand application scenarios. During the development of AR technology, researchers have proposed various implementation methods for AR systems. Among them, image-based AR systems have become mainstream due to their low requirements for hardware devices. This system integrates virtual information into the real environment by recognizing image features. However, when dealing with complex environments such as rapid movement and large-scale scenes, this system may experience delays and lag, which can affect the user experience. Design intent is the expected functionality, performance, and appearance expressed by the designer during the product design process. For intelligent assembly modeling, understanding design intent is crucial as it can help computers correctly interpret and simulate product functional requirements, as well as plan accurate manufacturing and assembly processes. Mo et al. [9] aim to explore how to intelligently capture and utilize design intent to achieve efficient and accurate product information modeling. Morín et al. [10] proposed a distributed AR architecture based on 5G networks. This architecture disperses the processing of image and video data across multiple nodes by distributing processing tasks in a 5G network, improving processing speed and stability.

The principle of a vibration frequency density meter is based on frequency measurement of vibration. When an object vibrates, the frequency of its vibration can be obtained by measuring its vibration displacement, velocity, or acceleration. The key to designing a vibration frequency density meter is how to accurately measure the frequency of vibration, as well as how to process and analyze the measurement results. Vibration frequency density meter is an instrument used to measure vibration frequency, which has wide applications in fields such as machinery, aviation, and automobiles. With the continuous progress of technology, computer-aided design systems have gradually become an important tool for designing vibration frequency density meters. Oliynyk and Taranenko [11] introduced a computer-aided design system for vibration frequency density meters. Including hardware and software technology implementation, as well as how to use the system for engineering experiments or scientific research. Augmented reality technology is a technology that combines virtual information with the real world and has broad application prospects. With the continuous development of augmented reality technology, more and more augmented reality applications have emerged. How to choose the most suitable application for oneself has become an important issue. Omerali and Kaya [12] introduced an augmented reality application selection framework using spherical fuzzy COPRAS multi criteria decision-making. This framework can help users choose the most suitable application from numerous augmented reality applications, improving the performance and effectiveness of the application. This article elaborates on the principles, design ideas, and implementation methods of this framework, and verifies its effectiveness and superiority through experiments. The experimental results indicate that this framework can help users better select and optimize augmented reality applications. The AR system combines virtual elements with the real environment to provide users with an augmented reality experience. Adaptive spatial ability training adjusts the representation of virtual elements based on user needs and environmental changes to provide a better user experience. At present, adaptive spatial ability training algorithms are mainly based on artificial intelligence technologies such as machine learning and deep learning. However, these algorithms have certain limitations when dealing with uncertainty and fuzziness, so it is necessary to introduce fuzzy logic to improve their performance.

Pérez et al. [13] conducted offline programming and simulation of multi robot manufacturing cells in a virtual environment. Program the robot through a virtual teaching device to verify its accessibility and collision avoidance performance. At the same time, optimize the motion trajectory and speed of the robot to improve manufacturing efficiency. Online debugging and correction of multi robot manufacturing units in actual manufacturing environments. Optical tracking of actual manufacturing units is carried out through cameras and other devices, and the tracking results are compared and analyzed with digital twin models. Revise the manufacturing unit based on the analysis results to improve manufacturing accuracy and efficiency. The multi robot manufacturing unit debugging method based on digital twins and virtual reality proposed in this article can improve the debugging efficiency and accuracy of the manufacturing unit, reduce debugging costs and risks. This method has broad application prospects and provides a new solution for the debugging of multi robot manufacturing units. Rojas et al. [14] conducted a series of experiments. The experimental results show that the adaptive spatial ability training algorithm designed using fuzzy logic can more accurately analyze user needs and environmental information, providing better virtual element adjustment effects. It explores how to use fuzzy logic to improve the adaptive spatial ability training effect of AR systems. Through the introduction of background knowledge, the importance of adaptive spatial ability training in AR systems and the advantages of fuzzy logic in dealing with uncertainty and fuzziness were elaborated. With the development of modern industrial technology, computer-aided intelligent assembly modeling technology has become an indispensable part of product design and manufacturing processes. This technology can optimize product design, reduce manufacturing errors, and improve production efficiency and quality through digital modeling and simulation. In computer-aided intelligent assembly modeling, capturing product information modeling for design intent is crucial. These intentions are usually conveyed and implemented through communication and collaboration between designers and engineers. And product information modeling is to describe and express these design intentions by establishing a digital model of the product, in order to facilitate subsequent simulation, optimization, and manufacturing. The functionality and performance of the product are the primary considerations for designers.

Tähemaa and Bondarenko [15] proposed a synchronous control and simulation method based on digital twins, which uses virtual reality technology to control and simulate industrial robot cells. Digital twin technology can establish real-time connections between actual industrial robot cells and virtual environments, achieving dynamic interaction and control. Virtual reality technology provides a high-fidelity environment for the simulation of industrial robot cells, which can simulate various complex work scenarios and conditions. Through this digital twin based synchronous control and simulation method, the control accuracy and work efficiency of industrial robot cells can be improved, production costs can be reduced, and a new implementation path for future intelligent industrial production is also provided. With the continuous development of technology, virtual reality technology and intelligent algorithms have become important tools in multiple fields and are playing an increasingly important role in coastal landscape design. Wang [16] explored how to apply virtual reality technology and intelligent algorithms to coastal landscape design. To improve design efficiency, optimize design schemes, and achieve better landscape effects. Virtual reality technology is a computer technology that creates a realistic, immersive virtual environment by simulating human visual and auditory perception. Wu and Han [17] adopted the Fuzzy Comprehensive Evaluation (FCE) method. The FCE method is a multi-level and multifactor comprehensive evaluation method based on fuzzy mathematics. It can fully consider the subjectivity of evaluation factors and comprehensively and accurately evaluate the performance of interior decoration design systems. The performance indicators of the system are divided into several factors, such as design creativity, aesthetic value, user experience, operation convenience, etc.

The design of an aircraft cabin is a complex and demanding task. There are numerous industrial design fields involved, such as seat design, tableware design, spatial layout, etc. Traditional design methods are often time-consuming and labor-intensive, making it difficult to meet the needs of modern aircraft cabin design. The emergence of computer-aided industrial design systems has provided new solutions for the design of passenger aircraft cabins. However, there are still some problems with the existing computer-aided industrial design systems for passenger aircraft cabins, such as low design efficiency, poor collaborative ability, and a lack of intelligence. Therefore, it is imperative to optimize the computer-aided industrial design system for passenger aircraft cabins. With the continuous progress of technology, the application of computer-aided industrial design systems in various industries is becoming increasingly widespread. The application of this system is even more crucial in the design of passenger aircraft cabins. Yuan and Niu [18] explored the optimization of computer-aided industrial design systems for passenger aircraft cabins. To improve design efficiency and reduce costs, and bring greater commercial value to related enterprises. The current AR technology is mostly based on the Lambert world hypothesis, which assumes that all surfaces are Lambert bodies, which limits its application in practical complex environments. Zhang et al. [19] proposed an augmented reality framework based on differential rendering, which identifies non Lambertian materials in the scene and accurately renders them. Specifically, the framework first performs deep learning on the input scene to identify non Lambertian materials. Then, use physically accurate ray tracing algorithms to render non Lambertian materials and generate high fidelity virtual elements. Finally, differential rendering technology is used to compare virtual elements with corresponding parts in the original scene, achieving precise augmented reality effects. To verify the effectiveness of the proposed framework, we conducted experiments in a series of challenging practical scenarios, including various non Lambertian materials and complex environmental lighting conditions. The experimental results show that the proposed framework can accurately render non Lambertian materials and achieve excellent augmented reality effects.

3 STRUCTURE ANALYSIS AND DESIGN OPTIMIZATION SCHEME OF CERAMIC PRODUCTS BASED ON VR AND CAD

With the improvement of people's living standards and the progress of industrial technology, ceramic products are widely used in daily life and industrial fields, such as tableware, tea sets, decorations, electronic devices and so on. However, the design and manufacturing stage of ceramic products involves complex structural analysis and optimization. At present, the structural analysis and design optimization of ceramic products are facing many challenges, including the following aspects:

Complex product structure: Ceramic products have various structures, such as layered structure, nested structure and complex shape, which brings certain difficulties to structural analysis and design.

Long design cycle: The traditional ceramic product design process needs to go through many links such as hand-drawing, modeling, firing, etc., which is too long to meet the rapidly changing market demand.

High cost: The manufacturing stage of ceramic products needs a lot of time and materials, and the failure rate is high, which leads to high cost.

In view of the above problems, it is necessary to seek new technical means to improve the design quality and efficiency of ceramic products. With the growth of computer technology and VR, CAD and VR provide new means for structural analysis and design optimization of ceramic products. Through CAD, designers can quickly establish a 3D model of ceramic products and conduct structural analysis and optimization; Through VR, designers can present ceramic products in virtual environment, which is convenient for users to observe and experience the details and characteristics of products in all directions. Therefore, the structural analysis and design optimization of ceramic products based on CAD and VR have important market demand. Simplifying the 3D complex model is one of the key factors that affect the whole VR system, that is, simplifying the model as much as possible without affecting the graphic accuracy, deleting the vertices and faces in the model, so that it can be displayed in real time at high speed without distortion. Based on VR and CAD, a scheme for structural analysis and design optimization of ceramic products can be proposed.

3.1 VR 3D Scene Simplification Algorithm

The organic combination of VR and ceramic product CAD design will guarantee the improvement of ceramic product design quality. The purpose of this algorithm is to reduce the complexity of the scene, while maintaining the key features and structure of the product, so as to improve the display effect and user experience of VR. The design idea of VR 3D scene simplification algorithm is mainly to reduce the complexity of the scene and maintain the key features of the product by preprocessing the 3D model of ceramic products, geometric algorithm processing and optimization processing.

Pre-processing of 3D model: Firstly, pre-process the 3D model of ceramic products, including model format conversion, model segmentation and model simplification, so as to simplify the subsequent scene. Geometric algorithm processing: by analyzing and processing the geometric shape of ceramic products, the corresponding geometric algorithm is used to simplify and smooth the model. For example, the Loop subdivision algorithm can be used to subdivide the model, and then the subdivided model can be converted into a triangular mesh model by triangulation algorithm to realize the smoothing and simplification of the model. Optimization: After geometric algorithm processing, the model needs to be optimized, including deleting redundant vertices, merging adjacent faces and optimizing the topological structure of the model, so as to reduce the complexity of the scene and improve the VR display effect. Figure 1 is a flow chart of mobile agent task analysis.

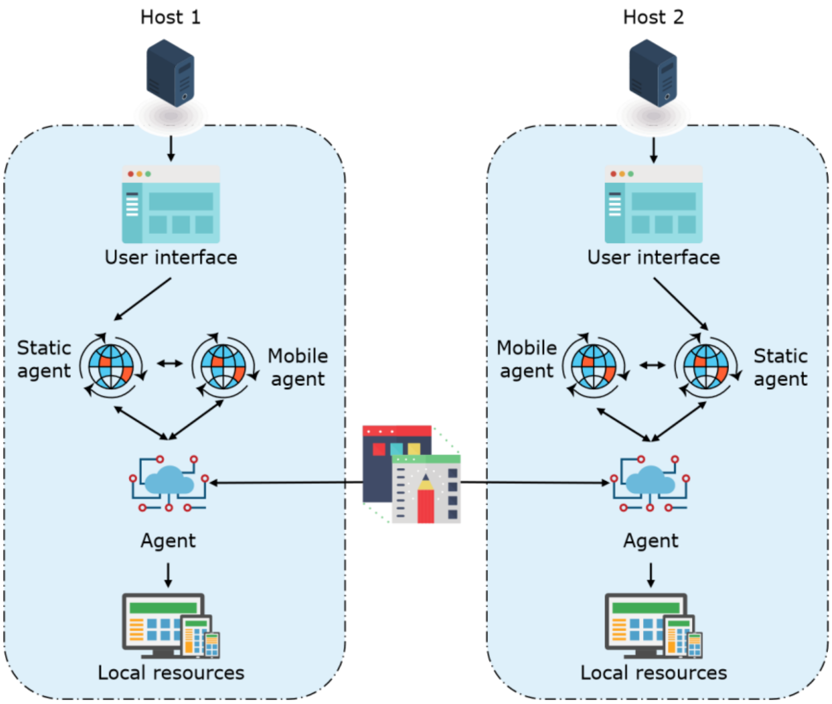

Figure 1: Flow chart of mobile agent task solving.

In the photon mapping algorithm, the classic rendering formula is as follows:

$$L_s(x,\psi_r)=L_e(x,\psi_r)+\int_{\Omega} f_r(x,\psi_i;\psi_r)L_i(x,\psi_i)\cos\theta_i d\omega_i \tag{1}$$

Where L_e is the radiant energy released from the surface, L_i is the incident energy in the direction L_i, f_r is the bidirectional reflection distribution function (BRDF), and Ω is the spherical surface in the incident direction.

The integral L_r in the above classical rendering formula can be decomposed into the following forms:

$$L_r=\int_{\Omega} f_r L_{i,l}\cos\theta_i d\omega_i+\int_{\Omega} f_{r,s}\left(L_{i,c}+L_{i,d}\right)\cos\theta_i d\omega_i+\int_{\Omega} f_{r,d}\cos\theta_i d\omega_i+\int_{\Omega} f_{r,d}L_{i,d}\cos\theta_i d\omega_i \tag{2}$$

Among them:

$$f_r = f_{r,s} + f_{r,d} \tag{3}$$

$$L_i = L_{i,l} + L_{i,c} + L_{i,d} \tag{4}$$

In the decomposed formula, the incident energy is decomposed into direct energy contribution $L_{i,l}$ of the light source, energy contribution $L_{i,c}$ of specular reflection of the light source and energy contribution $L_{i,d}$ of the light source after at least one diffuse reflection. BRDF is also decomposed into diffuse reflection part $f_{r,d}$ and specular reflection part $f_{r,s}$.

The 3D model of ceramic products is imported into the algorithm processing program. Preprocessing the imported 3D model, including model format conversion, model segmentation and model simplification. The model is subdivided, and then the subdivided model is transformed into a triangular mesh model by triangulation algorithm. The subdivision degree of the model and the parameters of the triangulation algorithm can be adjusted to achieve different simplification effects. Optimize the model after geometric algorithm processing, including deleting redundant vertices, merging adjacent faces and optimizing the model topology. The ceramic product model processed by VR 3D scene simplification algorithm is exported for display in VR environment.

3.2 VR Display Technology

According to different types of ceramic products, this article chooses suitable virtual display methods to achieve better user experience and product display effect. For some simple ceramic products, a full-angle display mode can be adopted, so that users can observe the products from any angle and understand the details and characteristics of the products. For some ceramic products with complex structure and rich details, we can use the display mode of key perspective to limit the user's perspective to the key parts of the product and improve the display effect and user experience. Through VR, interactive display between users and products can be realized, and users can observe and experience products in all directions through virtual operation, which improves the user's sense of participation and experience effect. The structure of VR image segmentation model for ceramic design is shown in Figure 2.

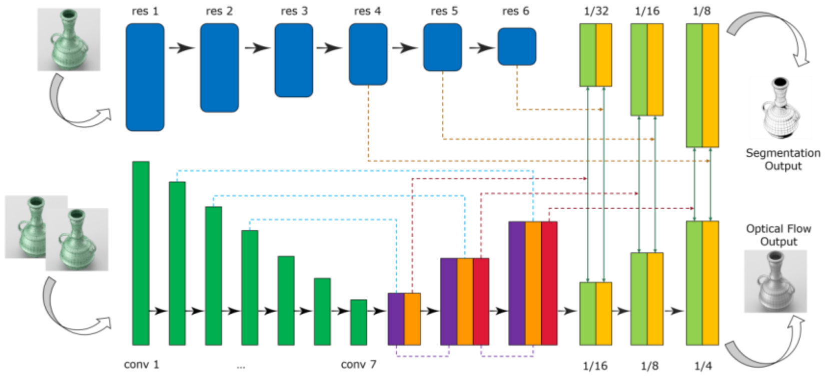

Figure 2: Structure of VR image segmentation model for ceramic design.

For a surface S, suppose we need to paste texture lines on the surface. First, we need to find out the relationship between space A and B. Make $AB = x$, so can get the following relationship:

$$\frac{R}{R+x}=\frac{R-h}{R} \tag{5}$$

After simplification, you get:

$$x=\frac{hR}{h-R} \tag{6}$$

There are,

$$\left(s-x^*\right)^2+\left(t-y^*\right)^2+z^*=\left(\frac{hR}{h-R}\right)^2 \tag{7}$$

Then the $B\left(x^*, y^*, z^*\right)$ on the curved surface corresponds to the $A(s,t)$ on the texture pattern one by one.

So, you can get:

$$\sin\theta=\frac{|AB|}{\left|A^*B^*\right|}=\frac{am+bn+cp}{\sqrt{\left(x_1^*-x_2^*\right)^2\left(y_1^*-y_2^*\right)^2\left(z_1^*-z_2^*\right)^2}} \tag{8}$$

Texture space coordinate (x,y) and the concave-convex model mapping area coordinate $\left(x^*, y^*, z^*\right)$ can form a one-to-one correspondence relationship, so as to better realize concave-convex model mapping.

x_{ij} is set as training data. First calculate the average of all elements in X :

$$p_0=\frac{1}{m*n}\sum_{i=1}^{n}\sum_{j=1}^{n}x_{ij} \tag{9}$$

Among them, $i=1,2,\cdots,m; j=1,2,\cdots,n$.

The normalization method used here is linear normalization:

$$y=\frac{x-MinValue}{MaxValue-MinValue} \tag{10}$$

The application of VR 3D scene simplification algorithm mainly focuses on the virtual display and user experience of ceramic products. The ceramic product model processed by this algorithm can be displayed in virtual environment with high efficiency and high quality, and the user's cognition and experience of the product can be improved. Efficient display: VR 3D scene simplification algorithm can greatly reduce the complexity of ceramic products in the virtual environment, improve the rendering efficiency of VR, and enable products to be presented to users quickly. High-quality display: The ceramic product model processed by VR 3D scene simplification algorithm not only retains the key features and structure of the product, but also smoothes and optimizes it, which improves the display quality and aesthetics of the product. User experience improvement: The ceramic product model processed by VR 3D scene simplification algorithm can provide users with more realistic immersion and interactive experience, and improve users' perception and experience of products.

3.3 Interactive Design in CAD Software

Realizing the interactive design of ceramic products in CAD software is one of the innovations of this article. Through interactive design, users can modify and adjust ceramic products in real time through VR, thus improving design efficiency and quality. The following is a detailed introduction to the implementation method and application of interaction design.

(1) Implementation method

The following steps are needed to realize the interactive design of ceramic products in CAD software:

3D model import: import the 3D model of ceramic products into CAD software for subsequent interactive design operations.

Design parameter setting: Set corresponding design parameters and features in CAD software, such as size, shape and material, so that users can modify and adjust them.

Application of VR: The combination of CAD software and VR enables users to modify and adjust ceramic products in real time through VR.

Interactive design operation: users can modify and adjust ceramic products through VR, such as changing product size and adjusting product shape. These operations will be reflected in the 3D model in real time, and the corresponding design parameters and features will be saved.

Export of design results: export the modified and adjusted 3D model of ceramic products for subsequent structural analysis and optimization.

(2) Application

Through interactive design in CAD software, users can design ceramic products more conveniently. The following are possible applications of interaction design in ceramic product design:

Size adjustment: users can adjust the size of ceramic products in real time according to actual needs, and observe the performance and effect of products in different sizes.

Shape modification: users can modify and adjust the shape of ceramic products according to their own creativity to achieve more unique and innovative design.

Material replacement: users can try to use different materials to design ceramic products and observe the influence of different materials on product performance and appearance.

Detail treatment: users can treat the details of ceramic products, such as carving and polishing, to improve the quality and aesthetics of products.

Through interactive design, users can observe and modify ceramic products in all directions in CAD software, which improves the efficiency and flexibility of design. This will not only help designers to innovate and optimize, but also provide users with better experience and satisfaction.

4 EXPERIMENT AND RESULT ANALYSIS

In this article, different types of ceramic products are selected for experiments, including ceramic bowls, ceramic cups and ceramic vases. By comparing the experimental results, it is found that the structural analysis and design optimization scheme of ceramic products based on VR and CAD can effectively improve the design quality and efficiency of products. Collect ceramic images in different quantities and scenes, including appearance, texture, color and other characteristics. In the case of different numbers of photos and different numbers, the ceramic design scenes are retrieved and experiments are carried out. The experimental results are shown in Figure 3.

As can be seen from Figure 3, in the ceramic design scene, the time of image retrieval increases with the increase of the quantity of network nodes, especially when the quantity of images is small. This may be because when there are few network nodes, each node needs to process more image data, which leads to an increase in retrieval time. In addition, due to the particularity of ceramic design scene, each image may contain many complicated features and details, which may also increase the difficulty and time of image retrieval. This is because with the increase of the quantity of nodes, the network can process more image data Moreover, thus improving the efficiency of image retrieval. In addition, multi-nodes can also distribute the load of the network, reduce the pressure of a single node, and further shorten the time required for image retrieval. Figure 4 shows the comparison of modeling accuracy of different algorithms.

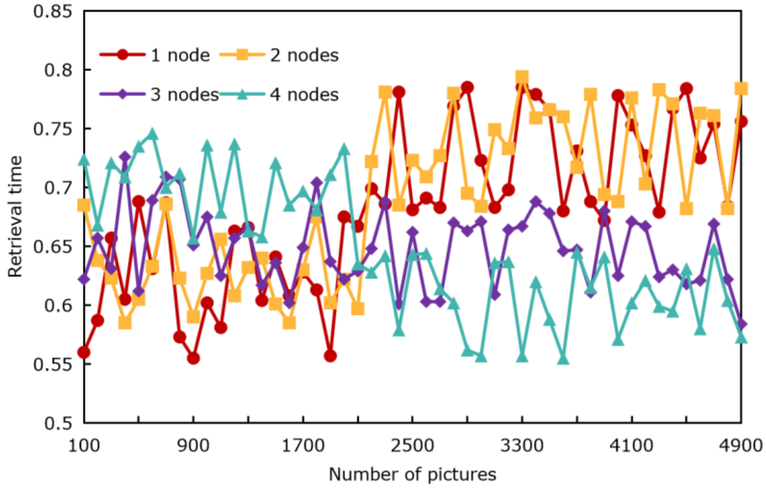

Figure 3: Image retrieval consumes time.

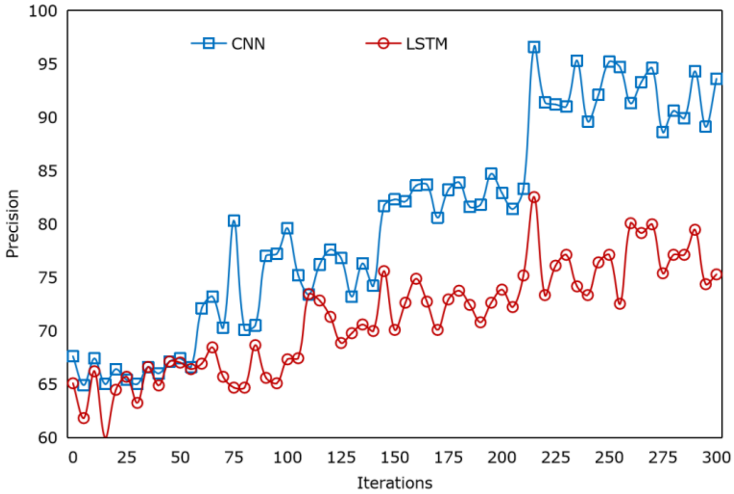

Figure 4: Accuracy of different algorithms.

The ceramic CAD modeling method proposed in this article improves the accuracy by more than 17% compared with the traditional SVM algorithm. This result shows that the ceramic CAD modeling method proposed in this article can construct the 3D model of ceramic products more accurately. The traditional SVM algorithm may have some limitations in the face of complex ceramic product features, but the CAD modeling method proposed in this article improves the modeling accuracy by introducing more features and optimization algorithms. Figure 5 shows the error test of different algorithm pairs.

In VR scene, it is very important to accurately locate the edge contour to improve the user experience and authenticity. When traditional algorithms deal with the edge contour of ceramic VR images, there may be inaccurate recognition or large errors. The algorithm proposed in this article can locate the edge contour more accurately and reduce the error by optimizing the algorithm and introducing more features.

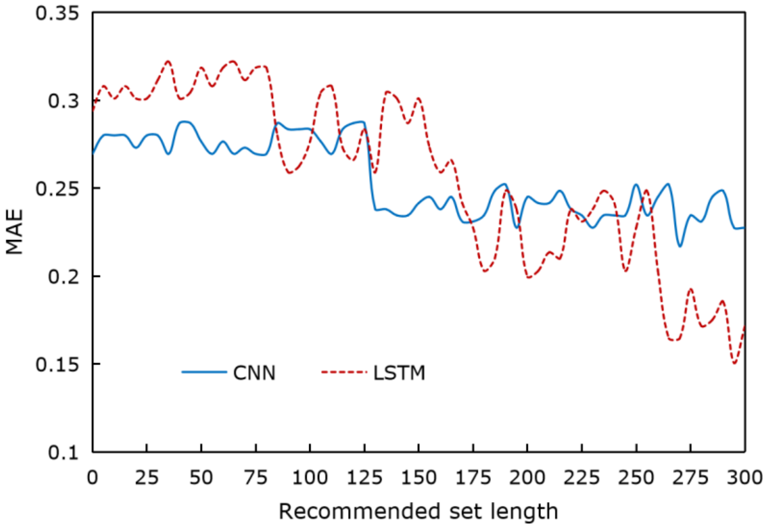

Figure 5: MAE comparison of virtual scene information feature recognition.

As can be seen from Figure 6, as the quantity of pixel points of feature information increases, the processing time of various methods increases accordingly. This is because more feature information needs more computing resources to process and analyze.

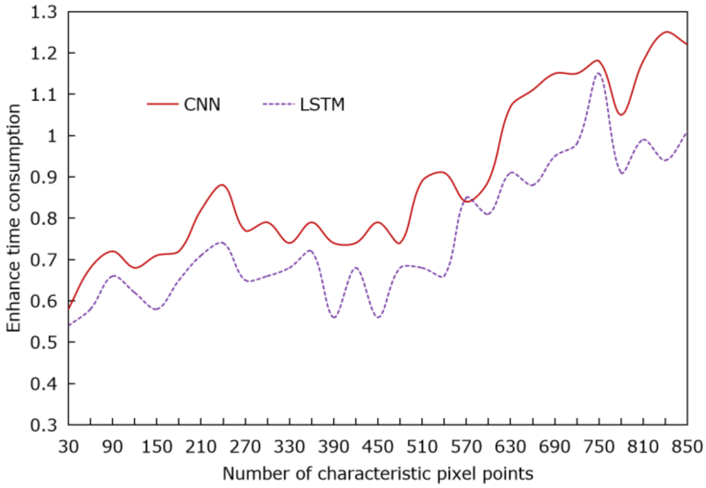

Figure 6: Enhanced image processing with different methods is time-consuming.

Among them, the traditional SVM method significantly increases the processing time with the increase of feature pixels. This is because SVM needs a lot of high-dimensional calculations when processing complex images, and the computational complexity is high. In contrast, the VR image processing method proposed in this article has significant advantages over SVM in processing time. Although the processing time increases with the increase of feature pixels, the increase is relatively small. This is because this method adopts efficient image processing technology and algorithm optimization, and can process complex image information in a short time.

Figure 7 shows the interactive scoring results of the constructed VR display system. The VR display system designed in this article shows strong advantages in interactive ability and user experience.

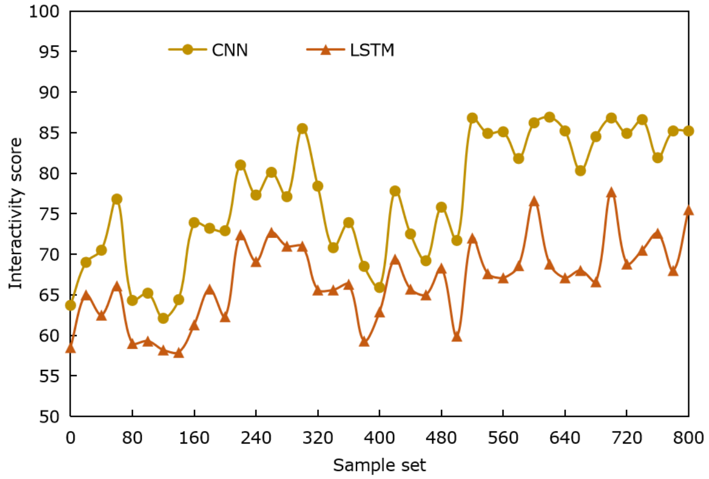

Figure 7: System interactivity score.

In the design stage of VR display system, this article focuses on the optimization of user experience. Through fine image rendering, smooth animation effect and realistic material texture, the virtual scene is more realistic and vivid, and users can feel the immersive feeling.

The ceramic CAD modeling method proposed in this article has obvious advantages in improving modeling accuracy and maintaining VR image clarity, which can better meet the needs of ceramic design field. This result also provides reference and enlightenment for the follow-up research and promotes the continuous development and progress in the field of ceramic design.

5 CONCLUSIONS

The product design of virtual ceramics is mainly to build a 3D model of ceramic products through new technologies, so as to facilitate customers to browse the product information intuitively. With the use of VR, the 3D CAD design of ceramic products can be effectively realized, and the ceramic products can be presented in a 3D form. In order to promote the use of CAD in ceramic design and assist the structural analysis and design optimization of ceramic products, this article proposes a VR 3D scene simplification algorithm based on photon mapping algorithm. The test results show that the VR image processing method has good performance in processing time and effect. Although the processing time increases with the increase of feature information, efficient image processing and recognition can be realized within an acceptable time, which is of great significance to practical application. Moreover, compared with the traditional SVM method, this method has better performance in processing complex images and is more suitable for practical application scenarios.

Through the comprehensive application of CAD and VR, this article provides a new solution for structural analysis and design optimization of ceramic products. However, there are still some limitations in this study, such as not considering the material characteristics and firing stage of ceramic products. Future research can further expand the application scope of the scheme and comprehensively consider the influence of more factors on ceramic product design. Moreover, we can also explore how to integrate artificial intelligence, big data and other technologies into the structural analysis and design optimization of ceramic products to achieve a more efficient and intelligent design process.

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Chuanbao Niu, https://orcid.org/0000-0001-5562-7503
Zhuoyue Diao, https://orcid.org/0009-0001-3209-1766

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