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Computer-Aided Design AND APPLICATIONS

Digital Protection and Interactive Display of Ceramic Art Integrating CAD and Human-Computer Interaction

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Abstract. Digital protection of ceramic art is an inevitable trend in its development. Previous digital protection methods have limitations, and the constructed three-dimensional models have certain errors, which cannot fully depict the state of physical ceramic artworks. Therefore, this article combines CAD and human-computer interaction technology to construct a digital 3D model and interactive display model for ceramic art and combines laser scanning, point cloud technology, Boolean operations, and CSG trees to improve the accuracy of 3D model construction. In addition, in order to improve the interactivity, sensitivity, and convenience of interactive display, this article constructs a multimodal fusion human-machine interaction platform, which enhances the experience of interactive display through multiple command signals. The experimental results show that compared with traditional methods, the 3D model constructed by this method has a lower coordinate error, can achieve restoration operations on the local morphology of ceramic art 3D models, and can more fully demonstrate the colour diversity and detail variability of ceramic art. In terms of interactive display, multimodal fusion instructions improve the convenience and smoothness of interactive display, providing participants with a better experience.

Keywords: CAD; Human Computer Interaction; Ceramic Art; Digitization; Interactive Display; Point Cloud Technology
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1 INTRODUCTION

Ceramics is one of the most excellent traditional practices in China. Ancient ceramic products, as art pieces, have been extensively tested and summarized by craftsmen to enhance the aesthetic appeal of ceramic products [1]. Solving the ceramic formula problem, which involves selecting ingredient ratios based on raw materials and target formulas to minimize chemical composition errors, is essentially a typical optimization problem. Unlike ancient times, where ceramic ingredients were used as ceramic formulas, modern ceramic formulas are chemical formulas composed of chemical compositions. In modern industry, ceramic products are widely used as excellent non-metallic functional materials in various fields such as architecture, aerospace, automotive industry, and military industry [2]. In the past, mathematical methods such as linear programming, gradient descent, and Newton's method were often used to solve optimization problems. With the introduction of intelligent computing, intelligent computing methods have good concurrency, robustness, and adaptability. Summarized the impact of several important parameters in particle swarm optimization algorithm on algorithm performance. This article elaborates on the current research status of particle swarm optimization algorithms both domestically and internationally, the emergence of ceramic formula problems, and the significance of using intelligent optimization algorithms to solve ceramic formula problems [3]. Several different improvement strategies have been incorporated to address the issues of particle swarm optimization algorithms being prone to local optima and slow convergence speed in the later stages. Based on the historical experience and flight conditions of particle flight processes, a new adaptive inertia weight strategy is designed by introducing global range values to adaptively change the inertia weight of each particle in the particle population. Using larger c and smaller cz in the early stages of the algorithm can make particles pay more attention to self-awareness, expand their range of flight in the solution space as much as possible, and increase population diversity. When the fitness value of a particle is closer to the global optimal value, it can be determined that the particle needs to explore its neighbouring areas more [4]. When the fitness value of a particle is closer to the global range value, it can be determined that the particle needs to expand its search range more.

The linear weighting method is used to address the issues of multiple optimization objectives and high difficulty in optimizing ceramic formulas. The closer the fitness value of a particle is to the global range, the more it needs to expand its search range. When the fitness value of a particle is closer to the global optimal value, it can be determined that the particle needs to explore its neighbouring areas more. This algorithm adaptively changes the inertia weight of each particle in the particle population by introducing a global range value. As the evolution process gradually decreases, the cz gradually increases, thereby enhancing the algorithm's global search ability in the early stage and the convergence speed in the later stage [5]. The APSO algorithm was applied to solve the ceramic formula problem, and the basic concepts and mathematical models of the ceramic formula problem were described in detail. Considering that in the early stages of the algorithm, the particle population needs to pay more attention to self-awareness, and in the later stages of the algorithm, more attention needs to be paid to group cognition. The proposed APSO algorithm was tested using standard test functions, and the test results showed that the APSO algorithm had significant performance improvements in optimization accuracy, convergence speed, and stability. By combining the Critical method to assign weight values to the main chemical components in ceramic formulations, the multi-objective problem is transformed into a single objective problem, which is solved using the APSO algorithm. Introducing virtual reality-based ceramic production methods into a technical education curriculum in a junior high school aims to explore their impact on student creativity and learning engagement and further explore new avenues for the digital protection of ceramic art [6]. As a part of technical education, ceramic making not only allows students to experience the charm of ceramic art firsthand but also deepens their understanding of ceramic art through practice. In addition, compared with paper-based teaching methods, VR-based teaching methods significantly improve students' behaviour, emotions, and social participation. In the experiment, 97 seventh-grade students were divided into three groups using VR-based methods, paper and pen methods, and traditional clay methods for learning. Students are more engaged in virtual environments, enabling better interaction and collaboration. This immersive learning experience not only enhances learning effectiveness but also enhances interest and identification with ceramic art [7].

With the improvement of the awareness of ceramic art protection, together with the development of science and technology, information technology, and Internet technology, a strong technical foundation has been provided for the digitalization of ceramic art [8]. The digital transformation of ceramic art can accurately capture various details of ceramic art, and the corresponding data can be replicated infinitely after digitization to maintain data consistency [9]. Digitized ceramic art can provide the original with data information for repair and reconstruction, and can also achieve interactive display through the Internet, promote the speed of communication, provide more abundant digital resources for more people, and break the constraints of time and space. In addition, the digitization of ceramic art provides more possibilities for interactive display, which can enhance the diversity of visual effects in an interactive display, provide more flexible interactive methods, break free from the limitations of physical space, and display more data information of ceramic art from multiple perspectives. It can also achieve the goal of displaying multiple exhibits at the same time. Therefore, the digital development of ceramic art is an inevitable trend for its inheritance, protection, and development. The integration of CAD and human-computer interaction technology has increased the possibility of large-scale inheritance of ceramic art, providing greater operational space for innovation. The key and difficult point of digital protection of ceramic art lies in how to improve the acquisition of detailed data on ceramic art and the restoration of colour expression in ceramic art [10]. The focus of the interactive display of ceramic art is on how to improve the effectiveness and accuracy of human-machine interaction. Therefore, this article combines economic and practical needs to choose to use laser scanning and point cloud technology to construct three-dimensional models of ceramic art data and effectively repair their colors. In addition, this article adds other interactive signals based on human-computer interaction gesture signals to improve overall interaction performance and accuracy.

2 RELATED WORK

As a key tool for the digital protection of ceramic art, three-dimensional digital technology is increasingly becoming a powerful supplement to traditional protection methods. In the virtual restoration stage, Marín et al. [11] accurately measured the area of the missing part based on the 3D degradation map of ceramic artworks. Regarding historical data and expert opinions, precise virtual repair modelling was carried out on the missing parts. These models not only achieve an average point density of 0.2 millimeters but also accurately reflect the original form and characteristics of ceramic artworks. In order to ensure the accuracy and authenticity of the restoration, the symmetry of ceramic artworks was fully utilized. Subsequently, representative missing parts were selected for repair, which may include decorative details of the head, body parts, or ceramic sculptures. In the model validation stage, a physical model printing was designed, and a comprehensive simulation test was conducted on the repaired ceramic artwork through digital simulation. Finally, we use photopolymerization 3D printing technology to print out the repaired parts. During the printing process, special consideration is given to the surface roughness and layer thickness of the material to ensure that the repaired part matches the material and texture of the original part. After printing, the repaired part is colored and anti-yellowing treated and accurately connected to the original ceramic artwork. After multiple modifications and reprocessing, the repaired part was finally accurately assembled, and the volume of the designed solid model was reduced to better adapt to the shape of the original ceramic artwork. Through non-contact digital restoration technology, the original form and features of ceramic artworks can be more accurately restored while avoiding further damage to the original cultural relics. Ming et al. [12] paid special attention to the suitability of assembly and interface handling to ensure perfect integration between repaired parts and original parts. This study not only demonstrates the enormous potential of 3D digital technology in the digital protection of ceramic art but also provides new ideas and methods for the protection and restoration of traditional ceramic artworks. In addition, digital restoration technology can provide reliable digital archives and replicas for the preservation and inheritance of ceramic artworks, allowing more people to appreciate this precious cultural heritage. We attempt to use 3D scanning, virtual repair modelling, and 3D printing techniques for non-contact repair and protection of damaged ceramic artworks, especially for damaged ceramic sculptures or decorative pieces.

With the increasing awareness of protecting intangible cultural heritage, "ancient ceramic restoration techniques" as a treasure of traditional Chinese culture have been officially included in the "National Intangible Cultural Heritage List of China". Deeply explore the application of virtual reality technology in the digital protection of ceramic art, especially in the potential of ancient ceramic restoration. To address this issue, Shi et al. [13] developed a VR-based ceramic restoration platform. This protection method not only improves the protection efficiency and reduces the protection cost, but also enables more people to understand and appreciate ceramic art through the Internet and other channels. In recent years, more and more regional institutions have adopted corresponding technologies to digitally protect local ceramic art. For example, the Jingdezhen Municipal Government and relevant institutions actively carry out digital protection of the intangible cultural heritage of ceramics. Tabib et al. [14] used 3D scanning technology to accurately digitize the details of the shape and decoration of Jingdezhen ceramics, forming a digital model. At the same time, using virtual reality technology, these digital models are reconstructed in 3D to build a virtual ceramic museum for tourists to visit online. In addition, 3D printing technology is also used for the physical printing of digital models, producing highly consistent copies of original works for research and exhibition purposes. In order to inherit and promote the culture of Jun porcelain, some Jun porcelain enterprises and research institutions have begun to explore the digital protection of Jun porcelain firing techniques. Tao [15] used microfilm to record the process and key technologies of Jun porcelain firing and conveyed them to the audience through the media. At the same time, virtual reality technology was also used to construct a virtual scene of Jun porcelain firing, allowing the audience to experience the charm of Jun porcelain firing firsthand.

At present, digital protection of ceramic art has achieved certain results but still faces some challenges. Firstly, digital technology needs to be constantly updated and improved to meet the needs of ceramic art protection. Secondly, digital protection requires a significant investment of funds and human resources and requires the joint support of the government, enterprises, and all sectors of society. In addition, digital protection also needs to address issues such as copyright protection and data security.

3 CONSTRUCTION OF DIGITAL 3D MODELS OF CERAMIC ART BASED ON CAD AND HUMAN-COMPUTER INTERACTION

3.1 Construction of Digital 3D Models for Ceramic Art

The construction of 3D models for ceramic art is based on obtaining accurate data information. Ceramic art has diverse forms of expression, diverse shapes, rich surface colours, and unique glaze textures. In digital protection, 3D scanning technology and virtual reality technology are often used as the main means to achieve the construction of 3D models. However, different ceramic art forms have unique characteristics and details, and it is necessary to choose corresponding effective and targeted technical solutions based on the characteristics of different forms to obtain the required data information. The information of the three-dimensional model of ceramic art consists of two parts, namely, the three-dimensional data information of form and the surface colour and texture data information. After completing the construction and optimization of the three-dimensional model based on form data, the texture image needs to be mapped to the corresponding position on the ceramic art form through manual mapping and texture mapping. This article comprehensively considers the characteristics of ceramic art and adopts 3D point cloud technology to obtain corresponding data information. It can directly and realistically reflect the form and structure of ceramic art, including rich attribute information and reducing the number of information acquisition times. It can capture tiny changes in ceramic art through scanning technology, and it has high flexibility to represent any form accurately. The non-contact acquisition of data information through 3D point cloud technology can reduce or even avoid harm and impact on ceramic art, ensuring the protection of the original.

This article uses laser scanning to obtain point cloud data. Compared with single-point scanning technology, this method has initiative, dynamism, speed, and high density. It obtains corresponding massive three-dimensional point cloud data information through the diffuse reflection of the laser beam on the ceramic art surface. The receiving device also receives distance and coordinate feature information, as well as horizontal angle a and vertical angle β. Let the laser pulse frequency be represented as λ_0, and its single round trip phase difference be represented as δ. The formula for describing the testing distance is shown in (1):

$$L_n = \frac{v}{2} \cdot (\frac{\delta}{2\pi\lambda}) \tag{1}$$

In the formula, the propagation speed of light in the atmosphere is denoted as v.

Set the coordinates of any point cloud to $P_n = (x_n, y_n, z_n)$, which can be converted into coordinates based on formula (1) and the obtained angle. The conditions that need to be met for the transformation of data matrices with the same points in two graphs are shown in formula (2):

$$\begin{cases} \forall p_n \in P, \exists q_n \in Q, \left\| Tp_n - q_n \right\| = 0 \\ F(R,T) = \min \sum_{n=1}^{N} \left\| Q_n - (R \times p_n + T) \right\|^2 \end{cases} \tag{2}$$

The conversion between different coordinate systems is shown in (3):

$$N_{new} \cdot N_{ini} \ (x,y,z)^T = R(x',y',z')^T + (\Delta x, \Delta y, \Delta z)^T \tag{3}$$

In the formula, the relative coordinates are described as $(x',y',z')^T$, the absolute coordinates are represented as $(x,y,z)^T$, the translation matrix to be solved is represented as $(\Delta x, \Delta y, \Delta z)^T$, and the transformation matrix to be solved is represented as R.

After obtaining point cloud data, further data processing is required, and feature extraction and segmentation are factors that affect the accuracy and effectiveness of 3D point cloud technology in obtaining data information. The feature point extraction method based on normal vectors is a method of describing the direction of a local surface by taking the normal vector of the vertical vector of the local surface. Its core idea is to obtain the angle between the corresponding normal vector and the normal direction of adjacent points by solving all data normal vectors in the point cloud data model. The size of the angle and the fluctuation between the two are positively correlated. A large angle indicates the presence of sharp geometric features, while a large angle indicates the presence of sparse geometric features. The schematic diagram of the angle between the normal vector and the normal vector in different surface regions is shown in Figure 1. The feature points of point cloud data can be selected by setting appropriate thresholds based on the trend of surface normal vector changes in point cloud data.

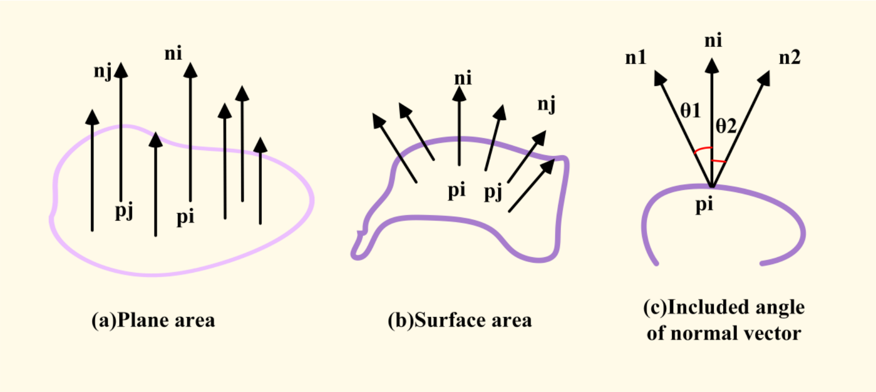

Figure 1: Schematic diagram of the angle between normal vectors and normal vectors with different surface areas.

Let the coordinates of a certain point be p_n, and its neighbouring h point set be represented as $\{p_1, p_2, ..., p_h\}$. Solve the mean of all points, that is, solve the centre of gravity o, as shown in formula (4):

$$o = \frac{1}{h}\sum_{n=1}^{h} p_n \tag{4}$$

Solve the minimum value of the normal vector of the least squares fitting surface, as shown in formula (5):

$$f = \sum_{Nbhd(p_n)} \left\| (p_n - o)\cdot i \right\| \tag{5}$$

Further transform the problem of solving the minimum value, as shown in formula (6):

$$\begin{bmatrix} \sum_n (x_n - o_x)^2 & \sum_n (x_n - o_x)(y_n - o_y) & \sum_n (x_n - o_x)(z_n - o_z) \\ \sum_n (y_n - o_y)(x_n - o_x) & \sum_n (y_n - o_y)^2 & \sum_n (x_n - o_x)(z_n - o_z) \\ \sum_n (z_n - o_z)(x_n - o_x) & \sum_n (z_n - o_z)(y_n - o_y) & \sum_n (z_n - o_z)^2 \end{bmatrix} \tag{6}$$

The coordinates of any point in the point cloud data are represented as x_n, y_n, z_n, and the corresponding centre of gravity coordinates are represented as o_x, o_y, o_z.

Unify the normal vectors with different directions obtained from different point cloud data points from a single perspective, and take the trend of the normal vector change at a certain point. Calculate the average angle between its normal vector and the corresponding h neighbouring point normal vector, as shown in formula (7):

$$f_n = \frac{1}{h}\sum\nolimits_{j=1}^{h} \theta_n \tag{7}$$

The angle between the normal vector of the data point and its neighbouring point normal vector is represented as θ_{ij}.

In order to reduce the impact of neighbourhood point size on the calculation time and feature point extraction performance of the normal vector, the neighbourhood radius constraint method can be introduced to obtain the optimal neighbourhood size, achieving the goal of reducing noise impact and improving efficiency. Let the neighbourhood radius threshold be represented as r, and each point is selected based on this pair of corresponding h nearest neighbours. The expression for the centre point of each point is shown in formula (8):

$$c_n = \frac{1}{\left| h_n \right|} \sum_{p_{nm} \in N^{h_n}(p_n)} p_{nm} \tag{8}$$

The centre point in the formula is represented as c_n and $\left\| p_{nm} \right\| < r$. The diffusion matrix and eigenvalues of the centre point are calculated, and the selection of retained data points and feature point extraction is carried out according to the size of the eigenvalues.

Let the point cloud set be represented as $P = \{p_n\}_{n=1}^{N}$, where the nearest point in the neighbourhood of each point is $N^{h_n}(p_n) = \{p_{nm}\}, n \le m \le h_n$, and the correlation matrix of each point is shown in formula (9):

$$C_n = \sum_{p_{nm} \in N^{h_n}(p_n)} (p_{nm} - c_n)(p_{nm} - c_n)^T \tag{9}$$

Calculate the eigenvalues $\{\lambda_0, \lambda_1, \lambda_2\}, \lambda_0 \le \lambda_1 \le \lambda_2$ of the correlation matrix and the corresponding eigenvectors $\{e_0, e_1, e_2\}$. Preserve the point set according to the set threshold, as shown in formula (10):

$$\frac{\lambda_2(p)}{\lambda_1(p)} < r_{12}, \frac{\lambda_3(p)}{\lambda_2(p)} < r_{23} \tag{10}$$

The feature points of the remaining points are determined by the minimum eigenvalue, as shown in formula (11):

$$\rho(p) \approx \lambda_3(p) \tag{11}$$

The eigenvalues of the points are represented as $\rho(p)$.

In order to verify the effectiveness of the three-dimensional model construction method in this article, the layout modelling method was selected for simulation experiments for comparative analysis. In the experiment, eight sets of ceramic art were randomly selected for coordinate data statistics, including the x-axis direction, y-axis direction, and z-axis direction. The precise coordinate position was taken as the origin, and the deviation direction was represented by positive or negative. The results are shown in Figure 2. From the statistical results in the figure, it can be seen that there is a certain deviation in the coordinate data of both methods in all three directions. However, in terms of deviation amplitude, the deviation amplitude of our method is significantly lower than that of the layout modelling method, especially in the y-axis and z-axis directions. Our method has more accurate coordinate positions and significant advantages.

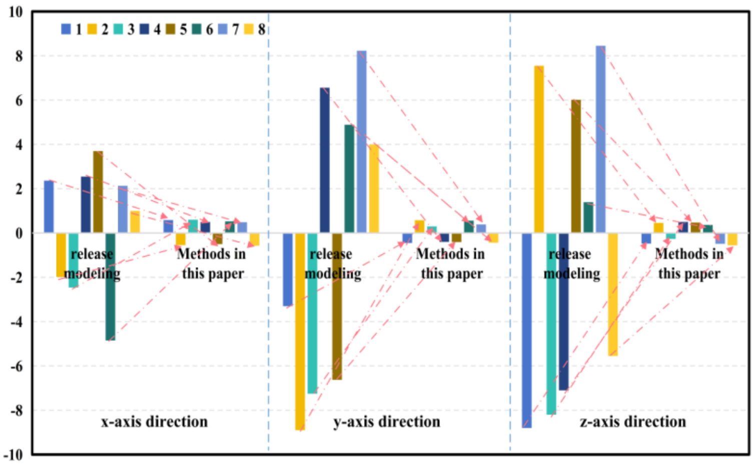

Figure 2: Coordinate data statistical results of two modelling methods.

In terms of point cloud registration, this article used multiple sets of sampling to test the error level of point cloud registration, and the results are shown in Figure 3. The results show that as the number of sampling points increases, the point cloud registration error rate remains stable and approaches zero, with only a small range of fluctuations. This indicates that the combination of laser scanning and 3D point cloud technology can maintain good stability under different point cloud quantities, improve the accuracy of point cloud registration, reduce error rates, and demonstrate obvious advantages. It can provide accurate, effective, and stable data support for the digitization of ceramic art and 3D modelling.

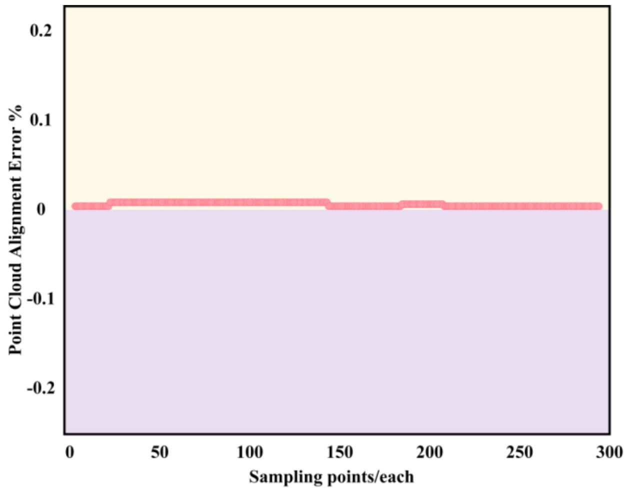

Figure 3: The registration error rate of point clouds under the combination of laser scanning and 3D point cloud technology.

3.2 Human-Machine Interaction Modeling of Digital 3D Models of Ceramic Art

In the process of digitizing ceramic art, due to the significant negative impact of the shape or environment of some ceramics themselves on the results of laser scanning, there is a significant difference between the constructed 3D model and the actual ceramic art form. Therefore, it is necessary to use CAD software to modify or recombine the already constructed 3D model locally. Considering that there is a certain random probability in the process of ceramic art production, the resulting ceramic form has a high degree of irregularity. In this paper, a spatial construction representation (CSG) based on entity Boolean operation is used to construct a human-computer interaction model, achieving the purpose of local modification or splitting of the ceramic art 3D model.

In 3D models, Boolean operation algorithms are mathematical methods used to handle the logical relationships between two or more 3D entities (such as polyhedra, meshes, etc.). These operations mainly include union, intersection, and difference, which are used to generate new 3D solids or modify the shape of existing solids. They provide a powerful and flexible tool for creating and modifying complex 3D shapes. Assuming the existence of two three-dimensional plane entities A and B, the basic idea of Boolean operations is to complete the final result through a set of preserved and modified faces, as shown in Figure 4. The union operation involves merging the outer faces of two entities, A and B. The intersection operation refers to the common part of A and B, which includes the faces inside B in A and the faces inside A in B.; The difference operation is to subtract the part of B from A, including the outer surface of A, and the new inner surface formed by B cutting in A.

In the process of 3D ceramic modelling, entity Boolean operations require the use of CSG trees to complete entity information and record between entities. Its nodes can store entity topology information, and different construction methods play a decisive role in its tree shape. However, the final 3D modelling result obtained is unique. CSG trees can achieve 3D modelling goals through traversal methods, entity deletion, entity modification, entity rotation, entity translation, and other operations.

In addition to the construction of three-dimensional ceramic models with human-computer interaction performance mentioned above, ceramic art also needs to achieve interactive display through human-computer interaction during the display process. In the past, a single interaction signal was used to convey interaction instructions in the interactive display process, which resulted in problems such as delayed communication of interaction information, low accuracy, and no response from the display platform. In order to ensure the effectiveness and reliability of ceramic art interactive displays, this article adopts a multimodal fusion human-machine interaction platform. In this platform, users can complete ceramic interactive display operations through gesture signals, language signals, and eye tracking signals. Considering the actual environment for the interactive display of ceramic art, a multimodal fusion human-machine interaction platform mainly uses gesture signals and other signals as auxiliary forms to complete instruction analysis, as shown in Figure 5.

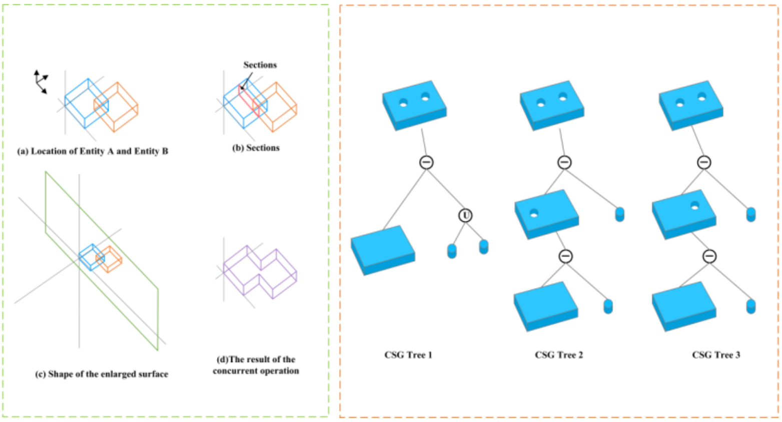

Figure 4: Ceramic 3D solids based on boolean operations and CSG tree representation.

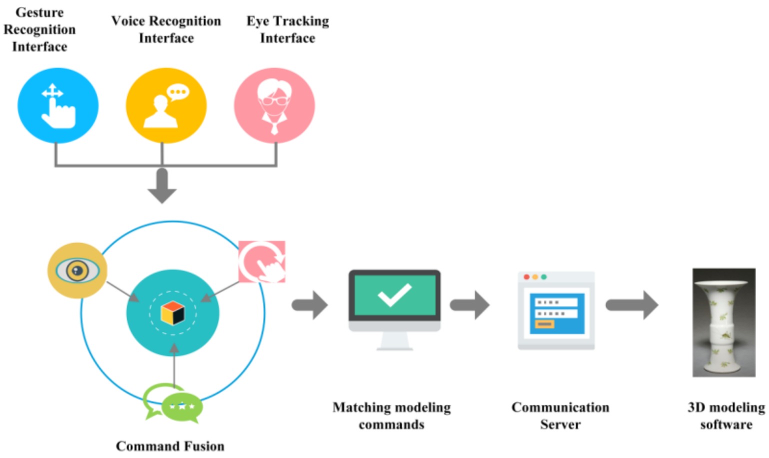

Figure 5: Multimodal fusion of human-computer interaction platform communication server process.

4 APPLICATION RESULTS OF DIGITAL PROTECTION AND INTERACTIVE DISPLAY OF CERAMIC ART BASED ON CAD AND HUMAN-COMPUTER INTERACTION

4.1 Application of Digital Protection of Ceramic Art Based on CAD and Human-Computer Interaction

In order to verify the practical application effect of laser scanning and 3D point cloud technology in the digitalization process of ceramic art, this paper selects a traditional digital 3D modelling method and the method used in this paper to construct digital 3D models for two different ceramic artworks. In practical applications, ceramic artworks not only have certain irregularity and occlusion in their own shape but may also have occlusion in corresponding accessories, as well as differences in the texture of 3D models constructed from different materials, all of which can affect the construction effect of 3D models. Among the two different ceramic artworks selected in this article, A is mainly plain white, while B is rich in colour and has accessories. The modelling results are shown in Figure 6. A ceramic art piece has a symmetrical proportion and smooth lines, with a natural colour that exudes a jade-like texture. Through the simple combination of green and red, it showcases the coolness of summer and the fun of teasing grasshoppers. The difficulty in constructing the 3D model of this ceramic artwork lies in showcasing the whiteness of the porcelain, the green colour of the image, and the smooth lines of the bottle itself. The results show that in terms of morphology, both the traditional method and the method proposed in this paper can construct the basic lines of the bottle body. However, at the bottle mouth, due to the low accuracy of the traditional method, there is a problem of uneven lines in some parts of the bottle mouth. This method improves the accuracy of point cloud distribution and, combined with laser scanning technology, can obtain the shape data information of ceramic artworks from multiple directions and angles, which can more realistically restore the shape of the solid bottle body. In terms of colour, the method presented in this article presents colours that are closer to actual colours, reflecting the hierarchical sense of similar colours, highlighting colour changes in details, and achieving higher accuracy. There are significant differences in colour in models constructed using traditional methods, and detailed changes cannot be fully presented.

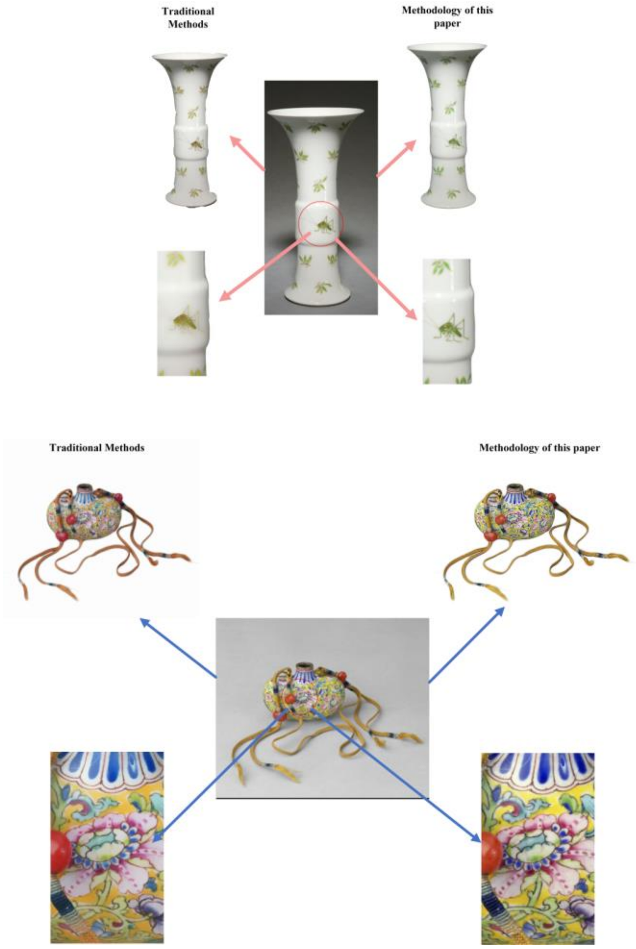

Figure 6: Digital 3D modelling results of two ceramic artworks.

The B ceramic artworks have bright and rich colours, unique shapes, and significant fluctuations in lines. Additionally, there are different materials of decorations that obstruct the ceramic artworks, increasing the difficulty of 3D modelling. The results show that traditional methods are prone to integrating the pearl texture and ceramic texture in jewellery during the modelling process, and there is a significant amount of noise data interference and deviation in colour presentation. In addition, there is a small difference in the texture presentation between ceramics and jewelry, which does not fully reflect the difference between the two. The method presented in this article can better showcase the vibrant colours of ceramic artworks in terms of colour presentation and can repair the brightness of colours based on corresponding data information. At the same time, the local repair function can better describe the bottle mouth shape and accessory form. The method presented in this article can fully demonstrate the texture difference between ceramics and accessories, and the constructed 3D model is more in line with the actual situation.

4.2 Application of Ceramic Art Interactive Display Based on CAD and Human-Computer Interaction

In terms of interactive display, this article chooses to increase the interaction between ceramic artworks and viewers through small games; that is, viewers can complete the production process of ceramic artworks through 3D models, thereby gaining a deeper understanding of the background story of ceramic artworks. In order to test the interactivity of ceramic art interactive display, this article randomly invited ten participants to conduct ceramic art interactive display application experiments, and the basic information of the participants is shown in Table 1.

Serial Number	*Gender*	*Cognitive level of handmade ceramics*	*Understand the level of the manual ceramic-making process*	*Likes to combine digitization and handicrafts*	*Digital Design of Handmade Porcelain*	*Type*
1	female	introduction	introduction	yes	have	initiate
2	male	interest	interest	yes	have	Interested parties
3	female	introduction	Not at all	no	have	initiate
4	male	expert	expert	yes	have	Experts and scholars
5	male	interest	introduction	yes	Insensitivity	Interested parties
6	female	Not at all	Not at all	yes	have	initiate
7	male	introduction	Not at all	yes	have	initiate
8	female	introduction	interest	yes	have	initiate
9	female	interest	Not at all	no	have	Interested parties
10	female	introduction	introduction	yes	have	initiate

Table 1: Basic information of participants in ceramic art interactive display games.

As shown in Figure 7, the feedback information statistics of participants participating in the ceramic art interactive display game are mainly divided into five aspects: smoothness of interactive display connection A, fun of interactive display B, satisfaction with human-computer interaction C, authenticity of 3D model construction D, and convenience of interactive interface E. The results showed that over 80% of participants agreed with the smoothness, fun, satisfaction, model authenticity, and boundary of the interactive display, especially in terms of fun. Only 10% of participants indicated that there was room for improvement in fun. In addition, there are still 20% of participants who believe that adding features such as zooming in on model details can allow participants to observe more closely in terms of 3D model authenticity. In terms of convenience in interactive interfaces, 20% of participants believe that it has higher sensitivity compared to other human-computer interaction interfaces, but lacks diversity in gesture signals and needs further improvement.

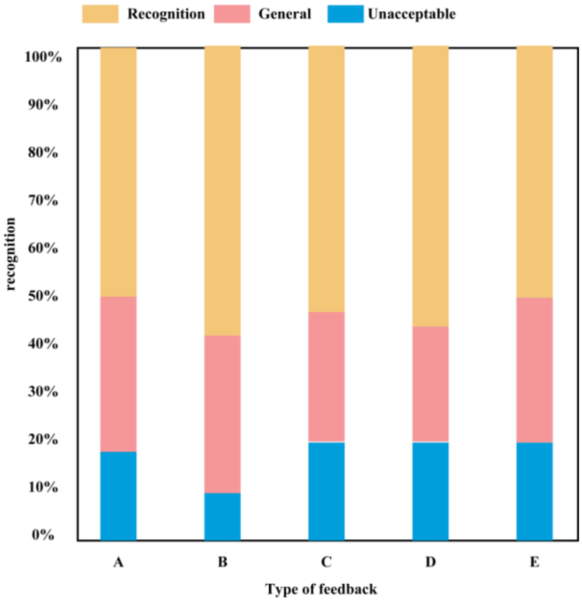

Figure 7: Statistics of feedback information from participants on interactive displays.

5 CONCLUSIONS

The digital protection of ceramic art is an inevitable trend in its inheritance, protection, and development process. In the past, digital methods mainly relied on existing digital products and technologies, with low accuracy and a significant gap between restoration and entity. With the development of information technology and technological advancements, the digitalization of ceramic art is becoming increasingly specialized and precise. The digital protection of ceramic art not only requires restoring the form of existing ceramics but also local restoration of their colour and form, presenting the original state of ceramic art as much as possible. Therefore, this article combines CAD and human-computer interaction technology to construct a 3D model and interactive display model for ceramic art. This article combines laser scanning technology and point cloud technology to improve the accuracy and colour restoration of the obtained 3D model data and constructs a human-machine interaction model based on entity Boolean operation spatial construction representation (CSG) to achieve the goal of local restoration of ceramic morphology. In addition, this article also adds a multi-modal fusion communication server for a human-computer interaction platform formed by multiple signals, enhancing the sensitivity and convenience of interactive display. The experimental results show that compared with traditional methods, our method can not only improve the accuracy of ceramic art forms, reduce coordinate errors, and improve point cloud registration accuracy, but also improve the accuracy and smoothness of 3D models; Moreover, it can truly reflect the chromaticity of ceramic art, fully showcasing the variability of colour details. The interactive display model in this article can provide participants with a better interactive experience, and improve the fun, convenience, authenticity, and fluency of interactive display. However, there are still many issues in the interactive display model that need further optimization, which is also an important aspect for further research in the future.

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