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Research on Intelligent Algorithm Optimization for Three-Dimensional Pattern Design in Ceramic Art under 3D Technology

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ABSTRACT

Ceramic art development is one of the long-standing cultural histories in China. With cultural heritage and artistic appreciation, this field enhances people's aesthetic qualities and opens the gateway to world cultural exchanges. In modern life, with the rapid development of technologies such as computers and big data, people have gained new insights and pursuits in ceramic art design innovation. Starting from the artistic characteristics of ceramic products, the shift from two-dimensional pattern design to three-dimensional pattern design has led to a series of outstanding works through bold attempts. This paper focuses on the intelligent optimization of algorithms for three-dimensional pattern design in ceramic art with the support of computer 3D printing technology. First, the big data analysis method is used to explore the evolution process of ceramic art pattern design and propose innovative ideas based on three-dimensional pattern design features. Using 3D printing technology and 3DMAX software overcomes problems such as single design and high cost in ceramic art design, establishing a three-dimensional pattern design system. Virtual reality technology optimises the 3D modeling process, improving the algorithm's intelligence, accuracy, and reliability. The research shows that the intelligent algorithm optimization for three-dimensional pattern design in ceramic art under 3D printing technology has improved productivity and contributed to the innovation of ceramic culture

Keywords: 3D Printing Technology, Ceramic art, Three-dimensional Pattern Design, Algorithm Optimization

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1. Introduction

Chinese ceramic art products have a long history and reflect the aesthetic and wisdom of ancient Chinese people, bringing artistic edification to later generations along with the changes of the times. Today, innovation and research on artistic products are a popular topic of concern for many artists, and ceramic art design has undergone new changes[1]. With the widespread application of technologies such as computers, big data, and intelligent algorithms, ceramic artworks under the demands of modern life have new opportunities and transformations [2]. They embody the concept of contemporary development in terms of modelling design, aesthetic style, graphic selection, and glaze usage, distinct from traditional ceramic artworks, highlighting the lifestyle of modern informationization. Various emerging technologies have played a significant role in ceramic art design, changing the level of art and technology and blending traditional culture with modern ideas. The origin of ceramic art design is based on the five elements of water, fire, and earth, which were essential daily necessities in ancient life [3]. It reflects the needs and aesthetic concepts of ancient people in their historical lives and reflects a society's level of economic development. The development of ceramic art design has undergone a long process, from an important cultural symbol to widespread production and use, from common daily necessities to emotional, cultural expressions. Gradually, it has developed its unique aesthetics and value, making it a new form of innovative culture. The uniqueness of ceramic works is also reflected in their long-lasting colors, making them valuable for conveying information and preserving critical cultural ideas [4].

Nowadays, the development of ceramic art design not only continues the craftsmanship and spirit of predecessors but has absorbed the national characteristics of ancient historical culture. As a common feature in ceramic art design, pattern decoration, in the form of colors, lines, characters, Chinese paintings, etc., is often employed in creating products. The pattern design of ceramic art usually reflects the decorative effect of the artwork while conveying its spiritual and cultural connotations to appreciators. This emotional record and set off have a unique artistic atmosphere and reflect the artistic development characteristics of different periods [5]. Ceramic art reflects a period's lifestyle and social features, requiring fixed production scale and quality requirements in the batch production mode. This modern assembly-line production reduces the characteristics of ceramics as artistic creations and weakens the artistic emotions conveyed by creators. With the development of the current era, the design ideas of ceramic patterns have also undergone new changes. More designers are shifting from two-dimensional pattern decoration to three-dimensional pattern design, which requires extensive support from computer algorithms. In summary, this paper explores the advantages of three-dimensional pattern design in ceramic art using computer 3D printing technology while intelligently optimizing and innovating its algorithm.

2. Current Development Status of 3D Printing Technology in Ceramic Art Design

The combination of ceramic art design with modern technology fully reflects people's current pursuit of a better life and the development of personalized differences. This innovative design and concept provide broad development space for ceramic works, allowing ceramic art to break free from the limitations of a certain direction or type [6]. The works' integration of numerous elements is mainly reflected through technological means and diverse aesthetics, enhancing applicability and artistic value and enabling ceramic art to reach a global audience. The application of 3D printing technology in ceramic art design is currently a key research area in the ceramic field for various countries. This material-enhanced manufacturing method uses materials such as powder metal and plastic, which are fused and stacked layer by layer to form three-dimensional objects [7]. 3D printing

technology has been widely used in various fields, and China has also provided strong support for its rapid development. Some foreign research literature suggests that 3D printing technology is essential to the new industrial revolution and its broad market space. Compared to traditional design and manufacturing techniques, it has sound effects regarding process flow, production efficiency, and cost savings [8]. 3D printing in producing artwork helps designers reduce material waste and enhance product strength while ensuring the beauty and artistic ideas of the works [9]. Traditional ceramic handcrafting has significant flaws due to mass production, which restricts the promotion of ceramic art. 3D printing technology can change the difficulty of mass-producing traditional ceramic artworks, simplifying the production process and improving efficiency.

In the 1970s and 1980s, foreign scientists proposed using material stacking, the precursor of 3D printing technology. The first 3D printer in the world was produced by an American company, using laser sintering technology to combine powder materials into new products. The powdered materials are melted, sintered, and solidified into the final product. China's development of 3D printing technology started relatively late, mainly led by several key universities conducting research [10]. Many automobile companies are researching this technology in the development trend of 3D printing technology applications. Companies such as Changan, BMW, Volkswagen, and Dongfeng have used 3D printing technology in engine manufacturing and gearbox gear components, achieving excellent results. However, using this technology is costly, and long-term adoption could impact the economic growth of the automotive industry. In addition, 3D printing technology is applied to human organs and biomimetic models in the medical field. Using 3D printing monitoring capabilities, prosthetics are implanted into patients to assist in rehabilitation and treatment. Foreign hospitals have also applied this technology to replicate internal organs, creating a fully functional liver, which brings breakthroughs to the medical field. Finally, in the ceramic art industry, the use of 3D printing models can batch-produce products, and this self-operating printing equipment has also achieved significant results in terms of success rate. Although the application of 3D technology in ceramic art design is still limited, it has excellent potential.

3. Three-Dimensional Pattern Design and Composition Display

3.1 Algorithm Optimization for Three-Dimensional Pattern Design in Ceramic Art

For ceramic art design, aesthetic patterns and graphic drawings are the main forms to showcase its characteristics and styles. Ceramic artworks of each era have different pattern designs and graphic markings, displaying the emotional changes of designers through various styles. As the finest embodiment of Chinese cultural tradition, ceramic exhibits are deeply loved by people at home and abroad for their unique color style and modeling craftsmanship. As an important part of cultural exchange, ceramic artworks not only satisfy people's aesthetic needs but also reflect the changing dynamics of the times and economy. 3D-printed ceramic products have been widely used in foreign fields such as machinery, automation, aerospace, and medicine and have established complete industrial entity models. We investigated their proportion in-depth, as shown in Figure 1.

Figure 1 shows that the proportion of ceramic products produced with 3D printing technology is relatively high in the automotive industry, mainly focusing on the interior decoration of automobiles. There are also significant proportions in aerospace, medical, and educational fields, where various aerospace electronic components and instruments utilize ceramic materials. This 3D printing technology emerged as a new technique from 3D modeling and data manufacturing, providing diverse product design solutions. With the increasing number of 3D-printed ceramic products, we have expanded the traditional two-dimensional design approach to incorporate three-dimensional effects in decorative patterns. Through three-dimensional pattern design, we aim to reflect the

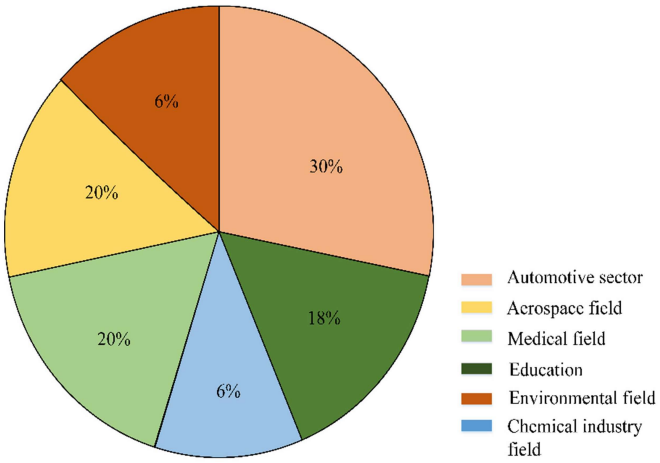

Figure 1. Proportional Development of Ceramic Products with 3D Printing Technology in Various Fields

decorative art and multifunctional requirements of ceramic works, utilizing art's rendering and showcasing power to enhance production efficiency. We analyzed the process of constructing three-dimensional patterns using 3D technology, starting with defining the 3D reconstruction formula as follows:

$$O(t) = \frac{(T_{OC} - T_i) \times (T_{c,i} - T_j)}{R(i)} \qquad (1)$$

where *R(i)* represents the reference points of the three-dimensional pattern in ceramic product design. By adding depth to the two-dimensional form, a three-dimensional prototype is achieved. This spatial vector includes the requirements of length, width, and height and is defined by the three-dimensional coordinates:

$$\begin{cases} x_0(k+1) = G(t) + x(k) + h(t) \\ y_1(k+1) = D(t) + cx(k) + u(k) \\ z_1(k+1) = S(t) + x(k) + h(t) \end{cases} \qquad (2)$$

The formula allows the reconstruction of planar points into three-dimensional structures, meeting the sensory changes required for three-dimensional patterns. Various elements of ceramic art forms are disassembled and combined according to the structural needs of three-dimensional patterns while still emphasizing the aesthetics of three-dimensional forms. The algorithm for composing the elements in a three-dimensional pattern design provides spatial and physical support for component principles. Despite the continuous use of 3D printing technology, there are still some shortcomings in the design process. Firstly, it cannot construct complex three-dimensional patterns and only creates simple line patterns. Secondly, various factors quickly affect printing efficiency, resulting in higher costs and an imbalance between service prices and value. Finally, the 3D printing process lacks dynamic monitoring, and the design product can only be checked after the device completes printing. Therefore, we optimize the intelligent algorithm using virtual reality technology, incorporating virtual monitoring into the 3D printing process to enhance efficiency. The optimized algorithm formula is as follows:

$$LIM \sum_{m}^{i,j} U * y + x + z / Gim \qquad (3)$$

Where *Gim* represents the variable model after adding virtual elements, the accuracy of the calculation results has been further improved. It can be seen that using virtual reality technology to improve the 3D printing process has achieved certain effects in ceramic art three-dimensional pattern design.

3.2 Morphology Design and Composition Display of Ceramic Art Three-dimensional Patterns

With the updating of the art design and concepts, modern design thinking better meets people's aesthetics and functionality needs than traditional, modern art effects. Modernist art has had a more profound impact on cultural development, mainly due to changes in artistic form and consciousness, which are more reasonable compared to the industrialization of traditional arts and crafts ceramics. As the interaction between artworks and human beings becomes more intensive, the connection between physical objects and the market becomes more important. Therefore, many ceramic designers believe they should conform to social development, combine art with vessels, and engage in production activities. In traditional ceramic art design, the fusion process of patterns and shapes can be divided into design proposal adoption, casting and forming, molding pouring, pattern drawing, and glaze composition, all of which are influenced by experience, material, and other costs. 3D printing technology in three-dimensional pattern design optimizes the traditional molding process, mainly through ingredient selection, 3D printing forming, ceramic embryo treatment, and finished product display. This technology can clearly and intuitively simulate the actual effect of three-dimensional pattern law in the design process. With precise virtual modeling and editable digital models, designers can adjust dynamically at any stage. We represent the three-dimensional model under digital design to obtain product information, which is more accurate and easier to modify in the design proposal than traditional methods. The assembly and analysis verification of the three-dimensional pattern mould can be completed on a virtual computer. Therefore, it can help achieve accurate forming of ceramic products. The structure diagram of ceramic art three-dimensional pattern design under 3D technology is shown in Figure 2.

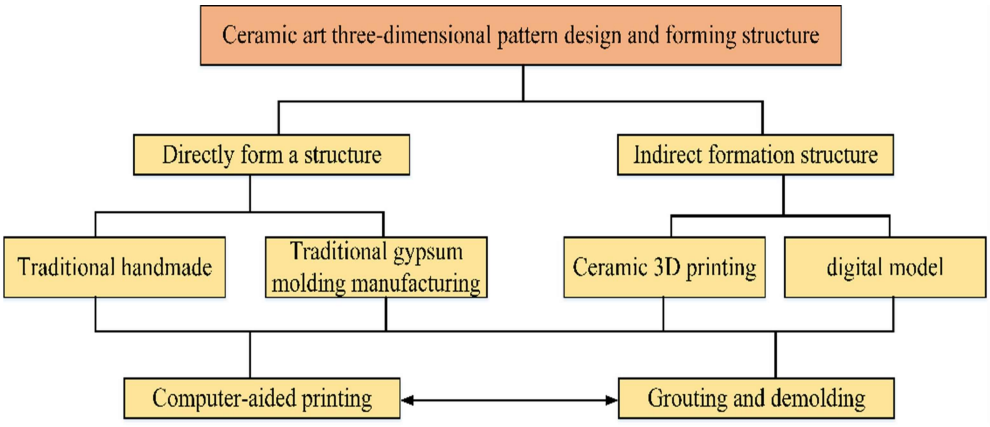

Figure 2. Structure diagram of ceramic art three-dimensional pattern design under 3D technology

From Figure 2, the design can be divided into direct and indirect compositions. The direct composition of three-dimensional patterns includes traditional manual methods and plaster mold methods, while the indirect composition includes 3D printing technology and digital mold forming. In the exhibition of ceramic art design, we use virtual projection technology to create a realistic and dreamy atmosphere, using scientific technology to bring viewers closer to ceramic artworks.

4. Algorithm Optimization of Ceramic Art Three-dimensional Pattern Design and Composition Display

In ceramic art design under 3D technology, suitable inkjet technology is used as the core content, where configured ink is added to the three-dimensional pattern, and organic material is mixed with ceramic powder from a planar angle. This inkjet printing technology can merge different additives and ceramic powders. We analyze the impact of different additive data on the final three-dimensional pattern design and use data modeling for calculation:

$$\begin{bmatrix} a_k \\ b_k \end{bmatrix} = \begin{bmatrix} I_0, I_1 \Delta t \\ I_2, 0 \end{bmatrix} \begin{bmatrix} a_{k-1} \\ b_{k-1} \end{bmatrix} + (u_k + w) = AX_k + B(u_k + w_k) \tag{4}$$

Where AX_k represents the characteristic coefficient of different materials, and incorporating the calculation results into the three-dimensional pattern design model can obtain the best combination plan. On the simulation system platform, input instructions are defined, and finally, a 3D printer is used for three-dimensional jet printing, producing ceramic embryos according to the set size and shape. Compared to traditional ceramic art manufacturing, this computer-aided printing technology is more straightforward in principle, and it generates more creative work in the design process. To promote the industrialization of ceramic art three-dimensional pattern design concepts, we must also consider the potential hazards of 3D printing technology. If the height and width of ceramic design works limit the printing material, products with many internal holes cannot be used. This study used virtual reality technology to optimize the three-dimensional pattern design process under ordinary 3D technology. We compared the two algorithms regarding cost usage, as shown in Figure 3.

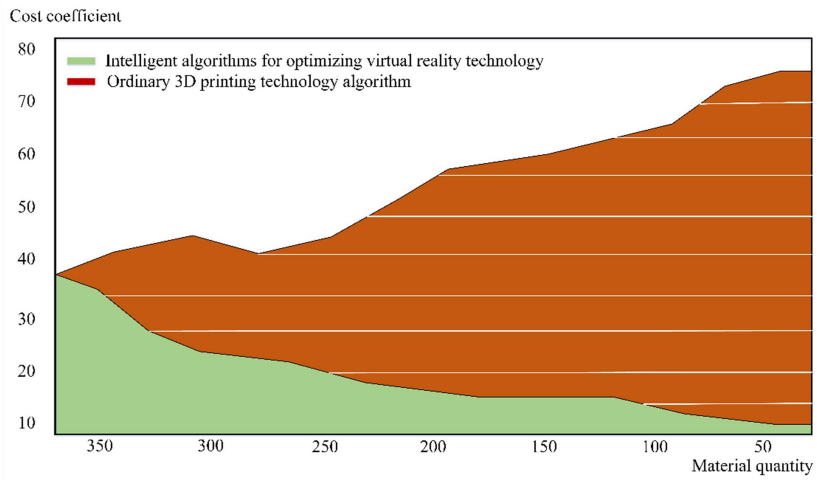

Figure 3. Comparison of cost usage between the two algorithms

Figure 3 shows that the intelligent algorithm optimized using virtual reality technology requires less material, which can bring new cost reductions to the design. The service price and material waste of ordinary 3D printing technology have limited its widespread promotion. In the exhibition of ceramic art three-dimensional pattern designs, we found that the three-dimensional form design has a realistic spatial effect, presenting a variety of changes in the centre of the light. This new technology has sparked a wave of enthusiasm in ceramic art creation.

At the same time, comparing the difference between flat pattern design and three-dimensional pattern, in actual display applications, the three-dimensional pattern shape can better highlight the unique charm of ceramic art products. Finally, using virtual reality projection technology to optimize the display of ceramic artworks enhances the close contact between the audience and the art pieces. In the virtual counter, ceramic art pieces are displayed in various postures, and the three-dimensional impact creates a three-dimensional image in the air, protecting the safety of art products and enhancing people's sensitivity.

5. Conclusion

With the development of the economy, people's needs have shifted from material to spiritual mediums. Many art products have been passed down in various forms, among which ceramics, the leading carriers of historical culture, hold an important position in social and cultural life. Traditional ceramic art design mainly focused on flat patterns and decorations with conventional lines and patterns. A new design concept emerges when modern concepts are integrated with ceramic art. This paper explores and optimizes the algorithm of ceramic art three-dimensional pattern design from the perspective of 3D technology. It uses big data analysis to investigate the development path of ceramic art design and compares the differences between flat pattern design and three-dimensional pattern design. The study utilizes 3D technology to improve the success rate of ceramic art design proposals while analyzing their production efficiency and cost. By employing 3D printing technology and virtual reality technology, it constructs a platform for displaying ceramic art three-dimensional pattern works, digitizes the elements in the virtual model, and accurately reflects the product's modeling characteristics. The research shows that 3D printed ceramic art with a three-dimensional pattern design achieves a connection between design and production, enhancing the feasibility of design proposals.

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