The Integration and Innovative Practice of CAD Technology and Big Data Analysis in Contemporary Daily Ceramic Design

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Abstract. This article mainly discusses the application effect of CAD (Computer Aided Design) technology and big data analysis in the design of daily-use ceramics and verifies whether it can improve the design efficiency and meet the market demand. Firstly, this article reviews the application status of CAD technology and big data analysis in various industries and points out the challenges in the field of daily-use ceramic design, such as long design cycles, high costs, and difficulty in meeting individual needs. In order to achieve the research purpose, this article adopts the experimental method and selects two representative daily-use ceramic design projects as the research objects. By integrating CAD technology and big data analysis, a data-driven design optimization model is constructed, and the design parameters are automatically adjusted and optimized. The experimental results show that the design products after integrating applications have significantly improved design efficiency, market acceptance, and user satisfaction. The conclusion shows that the integration of CAD technology and big data analysis provides new ideas and methods for daily-use ceramic design, which is helpful in improving design efficiency, reducing costs, and meeting market demand.

Keywords: CAD Technology; Big Data Analysis; Daily Ceramic Design; Design Efficiency; Market Demand
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1 INTRODUCTION

Ceramics is one of the most excellent traditional practices in China. As works of art, ancient ceramic products were developed by craftsmen through extensive experimentation to enhance their aesthetic appeal. In modern industry, ceramic products are widely used as excellent non-metallic functional materials in different fields such as construction, aerospace, automotive industry, and military industries [1]. Unlike ancient times, where ceramic raw material ratios were used as ceramic formulas, modern ceramic formulas are chemical formulas composed of chemical components. With

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the emergence of intelligent computing, intelligent computing methods have achieved good results in solving complex high-dimensional optimization problems due to their good concurrency, robustness, and adaptability [2]. Common intelligent computing methods include genetic algorithms, particle swarm optimization algorithms, etc. The problem of ceramic formulation needs to be solved, that is, selecting the ingredient ratio based on the raw materials and target formulation to minimize the chemical composition error, which is essentially a typical optimization problem. In the past, mathematical methods such as linear programming, gradient descent, and Newton's method were often used to solve optimization problems [3]. Due to its strong optimization ability, simple operation, and concise parameter settings, the particle swarm optimization algorithm has been favoured by many scholars at home and abroad. Several different improvement strategies have been integrated to address the problems of particle swarm optimization algorithms being prone to getting stuck in local optima and slow convergence speed in the later stages of the algorithm [4]. 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. When the fitness value of a particle approaches the global optimum, it can be determined that the particle needs to explore its neighbouring regions more [5].

By collecting and analyzing massive amounts of data during the manufacturing and repair processes, the model can predict and optimize parameter settings at various stages, such as kiln temperature control, glaze ratio, repair material selection, etc., to ensure the perfection of the final product [6]. Through the precise measurement and recognition capabilities of machine vision, designers can ensure that every ceramic work achieves a high degree of consistency in size, shape, texture, and other aspects, meeting the dual pursuit of quality and design sense by modern consumers. By scanning and modelling damaged ceramics, machine vision can accurately measure the size and shape of cracks and defects, providing detailed repair plans for repairers. The application of machine vision models proposed by some scholars in the design and repair of daily-use ceramics is not limited to defect recognition and quality control but also aims to promote continuous improvement in the design and repair process. In addition, this model can help designers and restorers better understand the behavioural characteristics of ceramic materials, providing a scientific basis for innovative design [7]. The results show that the model combined with machine vision technology performs well in improving recognition accuracy, accelerating repair speed, and reducing scrap rate, fully meeting the pursuit of high quality and efficiency in the field of daily ceramic design and repair.

The paper proposes to combine ceramic art creation experience with virtual technology, conduct in-depth research on traditional ceramic product manufacturing processes, and combine modular theory with user demand analysis methods. Regarding the modular creation experience of ceramic modelling design, some scholars have proposed a modular division method based on axiomatic theory, selecting a teapot for case analysis and design, achieving an interactive experience of modular creation in ceramic modelling design [8]. At the same time, research will be conducted on various methods of manual moulding, with a virtual ceramic art experience based on the drawing moulding method as the system. On the basis of determining the system functions, the Unity3D engine is combined with C # language to complete the writing of functional operation scripts, enabling the implementation of interactive effects. The specific research content is as follows: The necessity of researching virtual ceramic experiences has been determined through the current status of digital research on ceramic culture. The construction of a virtual pottery experience system based on Unity3D is of great significance in addressing the limitations of the traditional pottery experience. Simultaneously utilizing 3D modelling software to construct a realistic casting scene model, enhancing the user's sense of realism and immersion [9]. Summarize and analyze the system's functional modules based on user feedback data, providing direction for system optimization. Using the Kano model analysis method to determine user needs, and based on this, studying the specific functional module content of the system, sorting out the information architecture of the system, analyzing the interaction process of each functional page, and outputting the interaction prototype and interface design scheme of the system. The paper constructed an interactive system design

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model based on ceramic art production and verified the feasibility of modular design for ceramic modelling. Functional testing was conducted on the system, and a system testing process and evaluation form for system functional elements were designed. Not only can it break through the limitations of traditional ceramic venues, materials, techniques, etc., providing users with a good experience, but it can also promote the inheritance of ceramic culture [10].

The novelty of this article lies primarily in three key aspects:

It comprehensively discusses the integration of CAD technology and big data analysis within daily-use ceramic design, addressing a notable research void in this area.

A tailored fusion framework combining CAD and big data for daily-use ceramic design is established, offering theoretical direction for practical implementations.

Real-world case studies are analyzed to validate the efficacy and practicality of this integrated approach, providing valuable industry insights.

Regarding content structure, the article initially presents the research background, significance, scope, and objectives. Subsequently, it elaborates on the foundational applications of CAD technology and big data analysis in daily-use ceramic design. Following this, the theoretical framework for their integration is constructed, and the practical outcomes of this integration are demonstrated through case studies. Lastly, the article explores innovative practices facilitated by fusion technology, summarizes the research findings, and outlines future research directions.

Through combing the relevant literature, this study found that the use of CAD in ceramic design has achieved certain results, mainly focusing on 3D modelling, virtual reality display, structural optimization and so on. However, the research on the integration of CAD technology and big data analysis is still insufficient, especially in the field of daily-use ceramic design. The application of big data analysis in product design shows a rapid growth trend, mainly focusing on user behavior analysis, market trend prediction, product performance optimization, and so on. These studies provide a theoretical basis and practical reference for this study, but at the same time, they also point out the gaps and challenges in the current research.

2 RELATED WORK

With the improvement of consumers' aesthetic level and their pursuit of quality of life, the application of ceramic technology in daily ceramic design is becoming increasingly widespread and in-depth. In the field of daily ceramic restoration, ceramic technology also plays an important role. By organizing repair technology training courses and establishing repair studios, Ma et al. [11] aim to cultivate more professional ceramic repair talents and promote the healthy development of the ceramic repair industry. Traditional repair methods are often limited by materials and technology, making it difficult to achieve perfect repair results. Designers not only focus on the aesthetic appearance of products but also attach great importance to their comfort and environmental performance. Modern ceramic technologies, such as 3D printing and laser repair, provide new solutions for ceramic restoration. In addition, the plasticity and color richness of ceramic materials also add more creativity and possibilities to the restored works. Through continuous innovation in ceramic technologies such as underglaze painting, relief decoration, and microcrystalline glass composite, the dual improvement of product appearance and internal quality has been achieved. In addition, the introduction of intelligent production lines has greatly improved the production efficiency and quality stability of daily-use ceramics. Through online design platforms, consumers can choose their favorite patterns, colors, shapes, etc., to achieve a unique design experience. Marín et al. [12] accurately scanned the damaged area, generated a three-dimensional model, and then used ceramic materials for precise repair, not only restoring the integrity of the ceramic product but also preserving its original historical charm and artistic value and utilizing intelligent technology to optimize ceramic production processes and improve production efficiency and product quality. Meanwhile, with the help of artificial intelligence-assisted design tools, designers can quickly generate design solutions, shorten design

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cycles, and reduce design costs. Combining the flexibility and personalized needs of ceramic technology, we provide customized daily ceramic products for consumers.

CAD technology enables designers and consumers to immerse themselves in a world where virtual and real are intertwined, exploring the infinite possibilities of ceramic products. During the display and sales process, CAD technology enables ceramic moulds or finished products to be virtually placed according to actual usage scenarios, helping users evaluate their adaptability in home or commercial environments. CAD can also give each ceramic product a unique story background or cultural significance, enhancing users' emotional connections through multimedia elements such as animation and sound. Meanwhile, CAD can also display key steps and precautions during the repair process in real time, ensuring the smooth progress of the repair work. Ming et al. [13] used virtual tags or annotations to allow users to understand the stories and repair processes behind each ceramic piece, increasing the cultural and emotional value of the product. During the repair process, CAD technology can also help preserve and display the historical traces and repair process of ceramics. Combining IoT technology, AR can also provide preventive maintenance recommendations for ceramic products. By analyzing the usage environment and habits, AR systems can predict potential damage risks and provide maintenance or reinforcement recommendations in advance, thereby extending the service life of ceramic products. Designers can instantly adjust design elements such as colour, texture, and shape, and consumers can intuitively feel the impact of these changes on the overall design, thereby promoting democratization and personalization of the design process. Shi et al. [14] generate 3D models by scanning damaged areas and simulating the effects of different repair plans, which can help maintenance personnel or users choose the most suitable repair method. This interactive storytelling approach not only enhances the added value of the product but also promotes the dissemination and inheritance of ceramic culture. For damaged daily-use ceramics, precise repair guidance can be provided. This' try first, buy later 'experience greatly improves the comfort of users' purchasing decisions and reduces the return rate caused by size and style mismatches.

In the field of ancient ceramic preservation, VR technology achieves precise restoration and display of the appearance, structure, and production process of ancient ceramic artworks by constructing high-precision 3D models. In addition, VR technology provides a simulation platform for the restoration process of ancient ceramics, allowing restorers to try and optimize multiple restoration schemes without damaging the original object, greatly improving restoration efficiency and accuracy. In the design phase, Tao [15] uses VR platforms to quickly build and adjust 3D models of ceramic products, simulating the visual effects of different materials, colours, and textures in specific environments, achieving personalized customization and precise marketing. This non-contact display method not only avoids potential secondary damage caused by physical contact, but also allows scholars, restorers, and the public to freely explore in a virtual environment, deepening their understanding and cognition of ancient ceramic culture. By scanning the damaged area and constructing an accurate 3D digital model, repair personnel can perform virtual repair operations in a VR environment, evaluate the effectiveness of different repair materials and methods, and select the best solution. The application of VR technology in the design and restoration of everyday ceramics has opened up new creative spaces and practical avenues. Meanwhile, VR technology can also record the repair process, providing valuable materials for future research and teaching. In addition, VR technology can help designers better understand user needs and aesthetic preferences, promoting effective integration between design and the market. In terms of repair, VR technology also shows great potential for damaged daily-use ceramics. This virtual repair not only reduces repair costs but also improves the success rate and satisfaction of repairs.

3 PRINCIPLES OF BIG DATA ANALYSIS IN PRODUCT DESIGN

As a common article in daily life, daily-use ceramics should be designed with practicality, aesthetics, and culture in mind. Practicality requires that ceramic products have reasonable structure, comfortable grip, and durability; Aesthetics is reflected in the shape, color, and texture of the product, which needs to meet the aesthetic trend and market demand; Culture requires that ceramic

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design can inherit and carry forward traditional culture and reflect regional characteristics and ethnic customs. Furthermore, as consumer demand for personalized and tailored products grows, daily-use ceramic design must exhibit a high degree of flexibility and originality. CAD technology uses the powerful computing power and graphic processing power of computers to help designers complete product design quickly and accurately. It can not only draw two-dimensional drawings but also carry out 3D modelling, rendering, simulation and other complex operations. Incorporating CAD technology into daily-use ceramic design significantly enhances efficiency, cuts costs, and expands designers' creative horizons. Through CAD software, designers effortlessly construct 3D ceramic product models. They can comprehensively visualize the design by rotating, scaling, and translating the model, enabling timely identification and rectification of design flaws. Figure 1 illustrates the 3D model's panoramic display mode.

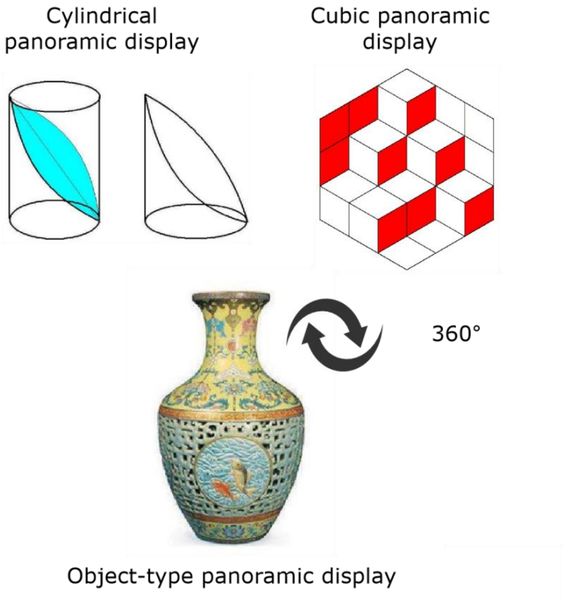

Figure 1: Panoramic display mode of 3D model.

Simulation: CAD technology can also carry out simulations, such as mechanical analysis, thermal analysis, fluid analysis, etc., to help designers predict the performance of products at the design stage and avoid problems and waste in subsequent production. Optimize design process: Through the integrated design environment of CAD technology, designers can manage design data efficiently, realize the integrated process of design, analysis and modification, and greatly improve design efficiency. Virtual reality display: Combined with virtual reality technology, the CAD model can be transformed into an immersive 3D scene, so that designers and consumers can intuitively feel the actual effect of ceramic products in the virtual environment, and provide strong support for product design and marketing.

Big data encompasses large-scale, diverse, and rapidly processed data collections, characterized by the 4Vs: Volume, Velocity, Variety, and Value. Product design, primarily originates from user behaviour, market sales, and product performance data, as cited in. These data contain abundant information, which can provide powerful data support for product design through in-depth mining and analysis. Big data analysis encompasses techniques such as data mining, machine learning, and predictive analysis. Data mining extracts valuable information and patterns, while machine learning predicts and classifies data via trained models. Predictive analysis utilizes historical data to forecast future trends.

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4 THEORETICAL FRAMEWORK OF INTEGRATION OF CAD AND BIG DATA

4.1 Construction of Fusion Mode

Feature Detection & Selection: Employ advanced data mining to extract ceramic design-related features from the preprocessed dataset, encompassing user preferences, market trends, and product performance metrics. A feature selection algorithm further refines these to the most impactful for design decisions. Let the original data set be:

$$X = \{x_1, x_2, x_3, \ldots, x_n\} \tag{1}$$

Where x_i is the i data sample. The goal of feature detection is to extract features closely related to ceramic design from each x_i:

$$F = \{f_1, f_2, f_3, \ldots, f_m\} \tag{2}$$

Feature detection can be expressed by the following formula:

$$f_j = \varnothing_j(x_i), \ for\ j = 1,2,3,\ldots,m \tag{3}$$

Where $\varnothing_j$ is the function to extract the j feature.

The goal of feature selection is to find a group of the most influential features $F' \subseteq F$. This can be expressed by the following formula:

$$F' = \mathrm{Select}(\mathrm{F}, \mathrm{Score}(\mathrm{F,X,Y})) \tag{4}$$

Among them Select is feature selection based on the model, Score is a function to assess the importance of features and Y is the target variable. The feature importance score is expressed as:

$$\mathrm{Score}(\mathrm{f_j,X,Y}) = \mathrm{Importance}(\mathrm{f_j,X,Y}), for\ j = 1,2,3,\ldots,m \tag{5}$$

This process helps to reduce the computational complexity, ensure that the model focuses on the most critical design factors, and improve the efficiency of the model.

Establishment of design optimization model: Based on the selected features, DNN (Deep Neural Network) is used to establish the design optimization model (as shown in Figure 2).

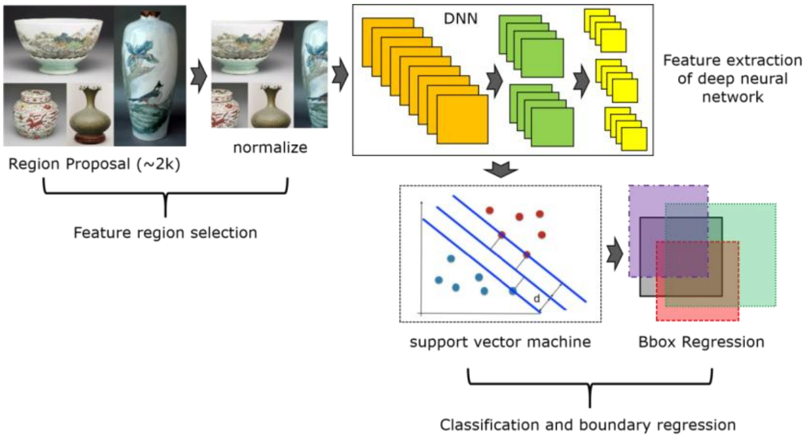

Figure 2: Optimization model.

Let the selected feature subset be F', and the design parameters are:

$$P = \{p_1, p_2, p_3, \ldots, p_k\} \tag{6}$$

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The model output is Y . DNN model can be expressed as:

$$Y = DNN \;\; F' \cup P;\theta \tag{7}$$

Where θ is the parameter set of the network. In order to minimize the loss function, this article uses a gradient descent algorithm:

$$\theta \leftarrow \theta - \alpha \nabla_{\theta} Loss \;\; Y_{\mathrm{true}}, \mathrm{Y}_{\mathrm{pred}} \tag{8}$$

Where α is the learning rate and $\nabla_{\theta} Loss$ is the gradient of the loss function with respect to the parameter θ ? The model has strong learning and forecasting ability, and can accurately predict key performance indexes such as market acceptance and customer satisfaction of products according to the input design parameters (such as size, shape, material selection, etc.). This not only provides designers with an intuitive preview of the design effect but also greatly shortens the design iteration cycle.

In CAD design optimization, the model integrates with CAD software to automate parameter adjustment and optimization. Designers can modify ceramic products' shape, structure, and material based on model predictions, aligning with market and user demands (Figure 3).

Figure 3: Example of ceramic product adjustment.

Model evaluation and iteration: assess and verify the design optimization model through actual production data and user feedback. If the performance of the model meets the expectation, it can be applied to the actual design; If the performance of the model is not good, iterative optimization is needed according to the evaluation results to improve the accuracy and reliability of the model.

Let the actual production data Y_{real} and the objective function of model evaluation be $\mathrm{Evaluate}$. Model evaluation can be expressed as:

$$\mathrm{Performance} = \mathrm{Evaluate} \;\; \mathrm{M} \;\; \mathrm{F}', \mathrm{P}; \theta_{\mathrm{M}} \;\; , Y_{\mathrm{real}} \tag{9}$$

Let the model iterative optimization algorithm be $\mathrm{Iterate}$, then the model iteration can be expressed as:

$$\theta'_{\mathrm{M}} = \mathrm{Iterate} \;\; \theta_{\mathrm{M}}, \mathrm{Performance} \tag{10}$$

Where θ'_{M} is the network parameter after iterative optimization?

In the above algorithm, the learning of θ_f and θ_M is usually realized by minimizing the loss function:

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$$\min_{\theta}\sum_{i=1}^{n} Loss\ \ M\ \ f\ \ x_i\ \ ,p_i;\theta\ \ ,y_i \tag{11}$$

Where y_i is the real label of the i sample. Through this iterative optimization process, the reliability of the model can be continuously improved. In this process, the error analysis and accuracy verification of the model (as shown in Figure 4) are key links, which provide a quantitative basis for the continuous optimization of the model.

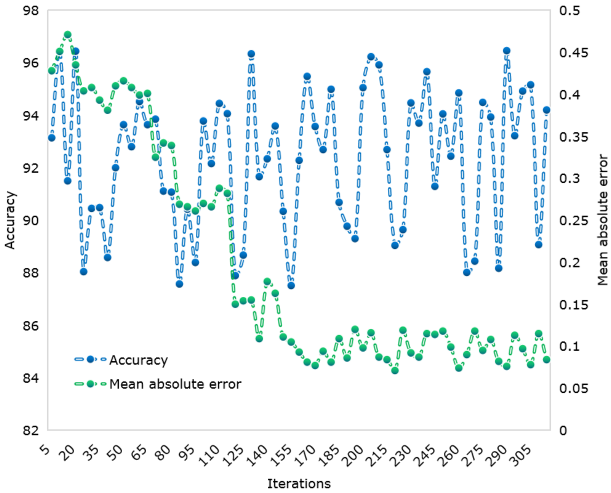

Figure 4: Accuracy results of the model.

The numerical results indicate the model's high accuracy in forecasting product market acceptance and user satisfaction, with a 92.5% success rate signifying correct predictions for most data points. The average absolute error of 0.11 highlights minimal deviation between predicted and actual values, underscoring the model's stability.

5 FUSION APPLICATION PRACTICE

5.1 Case Selection and Background Introduction

This article selects two representative daily-use ceramic design projects as the research object: one is the high-end tea set design project, which aims to create a high-end tea set with practicality, aesthetics and culture. The second is the children's tableware design project, which focuses on the safety and interest of products to meet children's use needs and aesthetic preferences.

5.2 Fusion Application Process

Data collection and pre-processing: For the two projects, various information such as user survey data, market sales data and product performance data were collected respectively. Then, the data is cleaned, duplicated and formatted to ensure the accuracy and consistency of the data.

Feature detection and selection: using data mining technology, the features related to ceramic design are extracted from the preprocessed data. For the high-end tea set design project, it mainly pays attention to the characteristics of users' aesthetic preference, material selection and price sensitivity; For children's tableware design projects, we mainly pay attention to the safety, fun and colour matching of the products, as shown in Table 1.

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Project Type	*Focused Features*	*Detailed Description*
High-end Tea Set Design	User Aesthetic Preferences	Utilizing data mining techniques to analyze user preferences regarding the appearance, style, and details of tea sets
	Material Selection	Analyzing user preferences and selection tendencies towards tea set materials, such as ceramic types, textures, durability, etc.
	Price Sensitivity	Assessing user sensitivity to tea set prices and the impact of price on purchasing decisions
Children's Tableware Design	Product Safety	Primarily focusing on the safety of tableware, including non-toxic materials, smooth edges, break resistance, and other characteristics.
	Fun and Interactivity	Analyzing children's needs and preferences for fun shapes, interactivity, and other aspects of tableware
	Colour Coordination	Studying children's preferences for tableware colours and the impact of colour coordination on attracting children's attention

Table 1: Overview of Feature detection and selection for ceramic design projects.

Establishment of design optimization model: Based on the selected features, the DNN algorithm is used to establish a design optimization model. The model predicts product market acceptance, customer satisfaction, and other vital metrics based on input design parameters. In CAD design optimization, the model integrates with CAD software for automatic parameter adjustment. Guided by model predictions, the designer refined the tea set and tableware shapes, structures, and materials, as illustrated in Figure 5 and Figure 6.

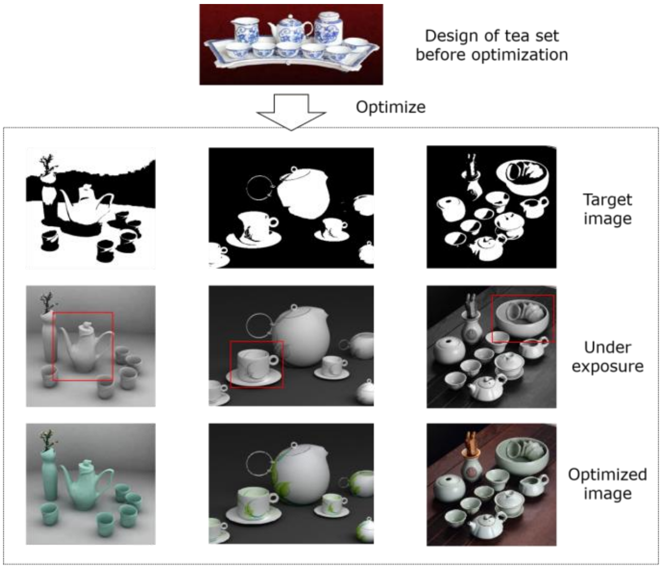

Figure 5: Optimization example of the tea set.

As shown in Figure 5, in the optimization example of the tea set, the designer accurately captured the dual demands of the market for simple style and practical function through model analysis and accordingly improved the line, proportion and handle design of the tea set to make it both beautiful and practical.

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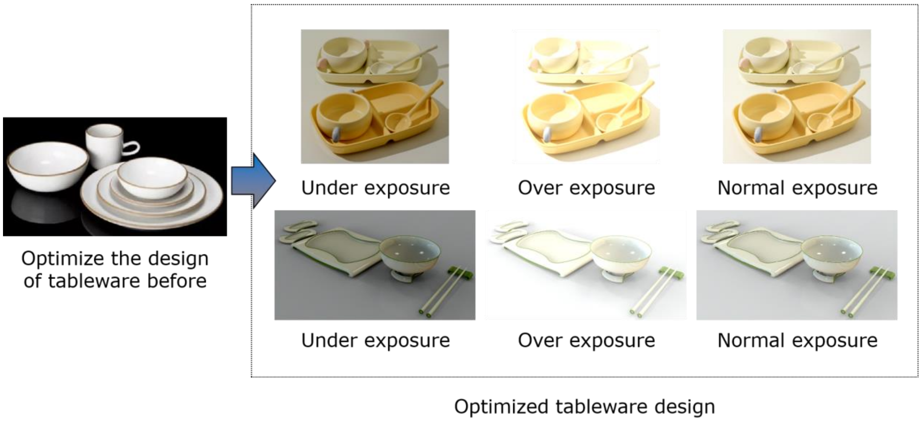

Figure 6: Tableware optimization example.

Figure 6 shows an example of tableware optimization, which shows how designers use the prediction results of the model to skillfully combine traditional elements with modern aesthetics, and innovatively design the shape and material of tableware to make it more in line with the habits and preferences of modern family dining.

Effectiveness evaluation: In order to comprehensively assess the actual effect of the integrated application of CAD technology and big data analysis, the following multi-dimensional comparative analysis is carried out. First of all, the remarkable improvement in design efficiency and quality is obvious. As shown in Figure 7 and Figure 8, the design cycle is greatly shortened after the integration application, and the overall quality of design works has also made a qualitative leap.

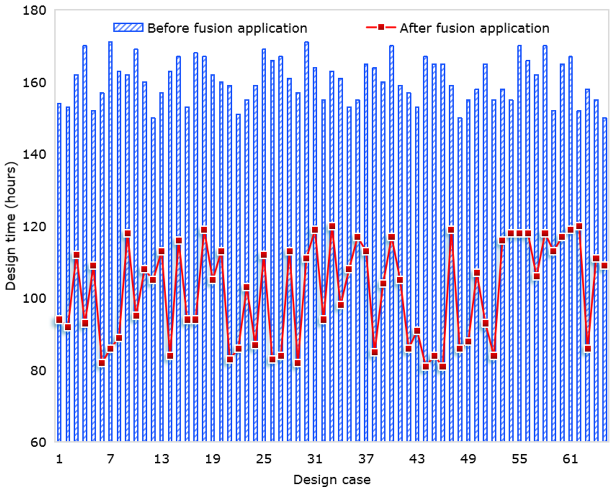

Figure 7: Comparison of design efficiency.

Secondly, this section further verifies the effect of the fusion application through actual production data and user feedback. As shown in Figure 9, the sales comparison chart clearly shows that the market performance of the designed products has improved significantly and the sales volume has increased steadily after the integration application. However, the comparison chart of user satisfaction in Figure 10 strongly proves that the design product after the integration application is closer to the user's needs, and user satisfaction has been greatly improved.

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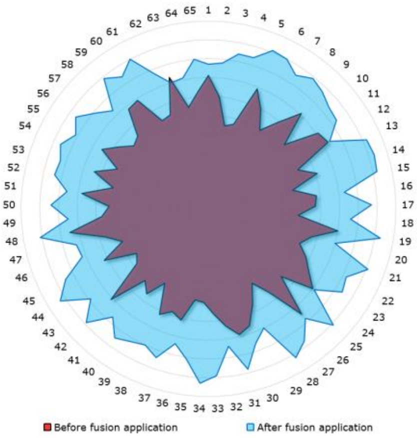

Figure 8: Comparison of design quality.

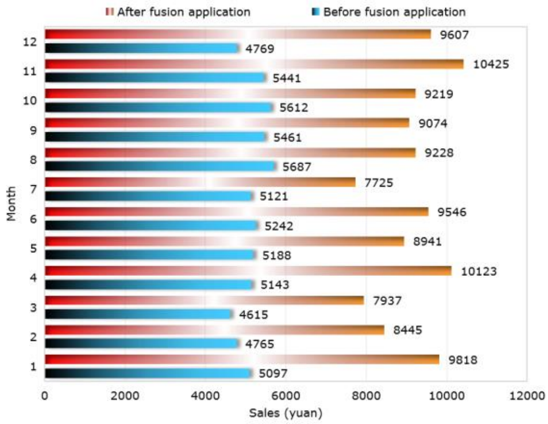

Figure 9: Sales comparison.

Figure 10: Comparison of user satisfaction.

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To sum up, the integrated application of CAD technology and big data analysis provides a new idea for the design of daily-use ceramics. By constructing a data-driven design optimization model, the design quality can be improved, and the consumer's demand for personalized and customized products can be met. At the same time, the practice of fusion application also proves the feasibility and effectiveness of this method.

6 EXPLORATION OF INNOVATIVE PRACTICE

6.1 Design Concept Innovation

Under the background of the integration of CAD technology and big data analysis, the field of daily-use ceramic design has ushered in the innovation opportunity of design concepts. Traditional design relies heavily on designer experience and intuition, whereas integration technology fosters a more scientific and systematic approach. This article introduces a "user-centered, data-driven" design concept, emphasizing user needs and preferences. By leveraging big data analysis to deeply mine user behaviour, it provides precise design guidance. Coupled with CAD technology's robust modelling and simulation capabilities, this enables swift design iteration and optimization, ensuring products meet market demands accurately.

6.2 Practical Challenges and Countermeasures

In practice, this article encounters challenges such as difficulty in data acquisition, uneven data quality and high algorithm complexity. In order to meet these challenges, we have taken the following countermeasures: First, enhance communication and collaboration with users and markets, establishing reliable data acquisition channels. Secondly, rigorously clean and preprocess the collected data to ensure its accuracy and reliability. Lastly, given the algorithm's high complexity, this article optimizes its structure and employs parallel computing techniques to boost operational efficiency.

7 CONCLUSIONS

This study delves into the application and integration of CAD technology and big data analysis within daily-use ceramic design. Through the development of a data-driven design optimization model, it achieves dual enhancements in design efficiency and quality. Additionally, the paper introduces innovative design concepts and techniques, offering fresh perspectives and approaches for daily-use ceramic design. The practice results show that the design products after the integration application are more in line with the needs of the market and users, and the sales volume and user satisfaction have been significantly improved.

Although some achievements have been made in this study, there are still some limitations. First of all, due to the limited access to data, some analyses may be based on incomplete data sets; Secondly, the selection and optimization of the algorithm still need further research and improvement; Finally, the practice process may be influenced by many uncontrollable factors, resulting in certain deviations in the results.

Anticipating the future landscape, CAD technology and big data analysis will witness sustained enhancement in their application and integration within the realm of daily-use ceramic design. Efforts will be directed towards broadening data acquisition avenues while ensuring superior data quality and integrity. Simultaneously, there will be ongoing refinement of algorithmic frameworks aimed at bolstering efficiency and precision. Consequently, it is anticipated that the amalgamation of CAD technology and big data analytics will usher in wider developmental horizons for daily-use ceramic design in the coming years.

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