

From Traditional Perspectives to Design Innovation

-- A Study on the Digital Restoration and Redesign of the Konghou in Mural No. 465 of Mogao Grottoes

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Abstract: This paper elaborates on the process of digital restoration and redesign of the konghou depicted in the murals of Mogao Grottoes' Cave 465 from a product design perspective. Through an in-depth analysis of the konghou's form, precise application of digital technology, and the clever integration of modern design concepts, this study not only achieves effective protection and inheritance of ancient cultural heritage but also explores innovative applications of traditional cultural elements in contemporary product design. This research is significant for promoting the digital preservation of cultural heritage and fostering the fusion of tradition and modernity.

Keywords: Product Design; Digital Restoration; Redesign Research; Konghou Art; Digital Technology Application.

1. Chapter 1 Introduction

1.1. Background and Motivation

The Dunhuang grottoes include Mogao, Yulin, Western Thousand Buddha Caves, Eastern Thousand Buddha Caves, and Five Temples. Among these, Mogao has the largest scale with 492 caves. There are 240 caves containing musical themes and 45 types of instruments, with the konghou being the second most numerous stringed instrument after the pipa, making it rich in research value. However, due to the passage of time and environmental influences, these precious konghou mural images face severe damage and fading. As a symbol of ancient music and a carrier of culture, the integrity and accuracy of the konghou mural forms are essential for studying ancient music, culture, and social life. Therefore, how to use modern technological means to accurately restore and redesign the konghou becomes the core issue of this study.

In recent years, domestic scholars have made significant progress in the field of digital preservation of cultural heritage, particularly in the digital restoration of immovable cultural relics such as grotto murals. Regarding the konghou images in the murals of Mogao Grotto No. 465, domestic research not only focuses on their historical background, cultural significance, and artistic characteristics but also actively explores the application of digital technologies in the restoration of these images. Scholars utilize advanced technologies such as high-precision scanning, 3D modeling, and image processing to conduct high-fidelity digital acquisition and reconstruction of the konghou murals, striving to restore their original appearance.

Moreover, integrating product design concepts, domestic research also emphasizes transforming the outcomes of digital restoration into culturally creative products that are both aesthetically pleasing and functional, such as konghou models, digital albums, and interactive experience installations. These diverse forms of dissemination and promotion serve to propagate and uphold traditional culture in a multifaceted manner.

1.2. Research Objectives and Significance

This paper aims to achieve the precise restoration of the konghou form depicted in the murals of Mogao Grottoes'

Cave 465 through digital restoration techniques, and on this basis, conduct modern product design research. The objectives of this study include: 1. Exploring the potential applications of digital technologies in the preservation and transmission of cultural heritage. 2. Uncovering the value of traditional cultural elements within modern product design. 3. Promoting the innovative integration of tradition and modernity to provide new perspectives for the revitalized utilization of cultural heritage. This research holds significant importance for advancing the digital protection of cultural heritage, enriching the cultural content of modern product design, and promoting the inheritance and development of culture.

2. Chapter 2 Analysis of the Morphology of the Konghou in Mural No. 465 of Mogao Grottoes

2.1. Background of the Murals and Overview of the Konghou Image



Figure 1. Dharmapala of the East in Mogao Grotto No. 465
Akshobhya Buddha Teaching

Mogao Grotto No. 465 is located on the second level at the northern end of the North Zone, and it is one of the few and earliest caves in Mogao Grottoes that features murals with

Tibetan Buddhist art as its theme. The cave consists of a main chamber, passageway, and antechamber. The main chamber has a pyramidal ceiling and is rectangular in shape, with a four-tiered circular altar set back slightly within the cave. In the center of the ceiling and on the four slopes, there is the thematic image of "The Five Buddhas Teaching," which possesses a strong aesthetic unique to Tibetan Tantric Buddhism and a mysterious appeal. Among these, the mural "Akshobhya Buddha Teaching" painted on the eastern slope of the cave is the subject of our digital restoration and redesign research. Mogao Grotto No. 465 is not only a sacred place of ancient religious beliefs but also a shining gem in the heritage of humanity.

As can be seen from the figure, the konghou is held by the Dharmapala of the East, and its overall shape resembles a spoon. The neck of the instrument is curved into an S-shape, and the bottom resonating box is similar to that of a lute, with visible scroll pattern decorations on the headstock [2]. It has four strings, which are tightly attached to the neck without tuning pegs. Regarding the long-necked, curved-neck instruments depicted in Dunhuang murals, terms such as "phoenix-headed konghou," "bent lute," and "bent-necked lute" have been used [3], characterized by their ornate appearance and prominent artistic effect, though their functionality for performance is questionable. According to historical literature, due to its elegant form, the konghou was confined within the royal palaces, gradually losing its core competitiveness—innovation. At the time when folk music flourished, its vitality waned [4]. Despite experiencing rises and falls over time, the unique artistic charm of the konghou continues to be cherished and passed down by later generations. This paper focuses on analyzing the characteristics of the konghou's form in the murals, including

its shape, structure, patterns, and other aspects. Through high-definition scanning and image analysis techniques, we extracted basic information such as the outline lines and color distribution of the konghou, providing reliable data support for subsequent digital restoration.

2.2. Artistic Value and Cultural Connotations of the Konghou Form

The form of the konghou in the murals of Mogao Grotto No. 465, with its delicate brushstrokes and vivid depictions, reflects the ancient artisans' love and pursuit of music. This artistic image not only holds a high aesthetic value but also carries rich cultural connotations. As an important musical instrument along the Silk Road, the design of the konghou not only demonstrates the exquisite craftsmanship of ancient artisans but also reflects the prosperity of music culture at the time. The konghou forms in the murals often combine with images of celestial beings and dancing figures, together forming lively and harmonious scenes, conveying the ancient people's yearning and pursuit of a better life. Therefore, the form of the konghou in the murals of Mogao Grotto No. 465 is not only a treasure of ancient art but also an important source of information for studying ancient music, culture, and social life. By thoroughly analyzing the form of the konghou, we can reveal its important status and cultural significance in ancient society, providing a solid theoretical basis for subsequent digital restoration and redesign.

3. Chapter 3 Digital Restoration Techniques and Methods

3.1. Digital Image Processing Techniques

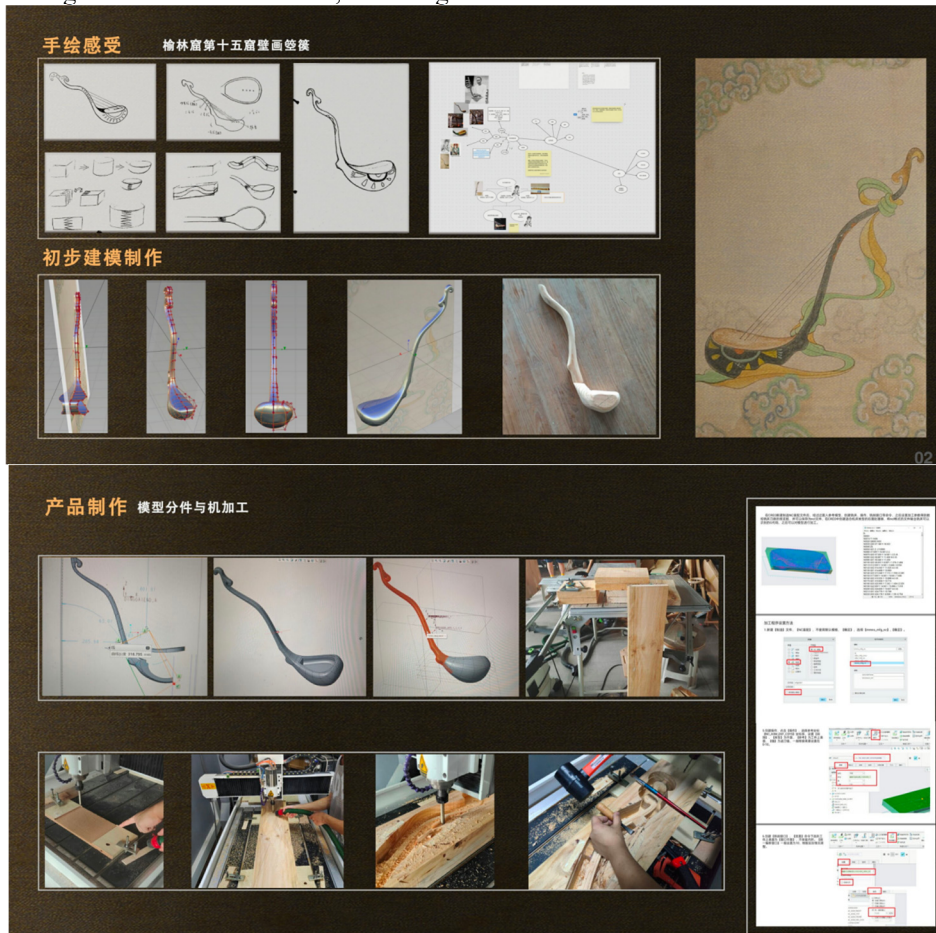


Figure 2. Initial Process of Digital Modeling

Firstly, improve the quality of the mural images through pre-processing techniques such as noise reduction and enhancement; then use techniques like image segmentation and edge detection to extract the outlines and detailed features of the konghou; finally, restore the original colors and textures of the konghou using color correction and texture synthesis technologies. The integrated application of these techniques provides high-quality image material for subsequent 3D modeling and product design.

3.2. 3D Modeling and Virtual Reality Technology

Based on the konghou image materials extracted through digital image processing techniques, construct a 3D model of the konghou using 3D scanning and modeling software. By finely adjusting parameters such as the size, proportions, and shape of the model, ensure that it remains consistent with the konghou form in the original mural. At the same time, utilize virtual reality technology to integrate the 3D model into a virtual environment for display and interactive experiences, providing viewers with a more intuitive and vivid visual experience.

3.3. AI-Enabled Digital Restoration

Automatically identify and classify different types of damage in the murals, such as cracks and faded areas, using deep learning algorithms. By training neural network models, predict the original colors and textures of the murals, thereby restoring their original appearance digitally, improving the efficiency of the restoration work, and enhancing the accuracy and consistency of the restoration. For the restoration of complex patterns and details, AI technology can provide more refined results, making the restored images closer to the original state of the murals. Additionally, intelligent algorithms can help generate multi-dimensional datasets of the murals, facilitating further research and analysis.

4. Chapter 4 Modernization Study of Konghou Product Restoration

4.1. Design Philosophy and Principles

In the process of modernizing the konghou product restoration, the author adheres to a design strategy that integrates cultural inheritance with modern innovation, balancing artistic aesthetics with product functionality, and placing user experience at the core to create an instrument that embodies traditional culture while meeting modern aesthetic and performance requirements.

4.1.1. Cultural Inheritance and Innovation: Integrating "Form Follows Function" with "Cultural Semiotics"

Emphasizing the principle of "form follows function," the design must respect and draw inspiration from the cultural connotations and artistic characteristics of the ancient konghou while ensuring that these elements serve the core function of a modern instrument—its performance capabilities. Utilizing modern materials science and technological means, the sound quality and durability of the instrument are optimized, achieving a perfect blend of traditional elements with modern technology, thus realizing "ancient resonance in contemporary sounds." A deeper exploration of the konghou and its cultural background leads to the selection of representative patterns, colors, and symbols

as design elements, abstracted or reconstructed through modern design techniques to express traditional cultural symbols in a new form, enhancing the cultural identity and contemporaneity of the design. Simultaneously, maintaining respect for the "spirit" of the ancient konghou ensures that the design works become a bridge connecting the past and the future.

4.1.2. Emphasizing Both Artistry and Functionality: Balancing the Principle of "Aesthetic Unity with Functionality"

While pursuing the vibrant and colorful decorative appearance reminiscent of Dunhuang murals, the design of the decoration must be based on not compromising the acoustic performance and playing experience of the instrument. Environmentally friendly and durable coatings and technologies, such as water-based paints and laser engraving, are employed to maintain visual impact while ensuring the instrument's durability and eco-friendliness. The internal structural design strictly follows acoustical principles, utilizing modern technology to enhance sound quality and volume, ensuring outstanding performance in modern concert halls and performance venues.

4.1.3. User Experience at the Core: Applying "Human-Centered Design" and "User Research"

In the design strategy, greater emphasis is placed on human-centered design (HCD), positioning the user at the heart of the design process. Through user research, interviews, prototype testing, and other methods, a deep understanding of the needs, habits, and preferences of performers is gained. Based on the research findings, adjustments are made to the dimensions, weight, grip feel, and other details of the instrument to ensure comfort during extended playing sessions. Additionally, adjustable design elements such as height-adjustable legs and angle-adjustable playing surfaces are considered to accommodate the personalized needs of different players. With the assistance of modern technological means, such as virtual reality (VR) and augmented reality (AR) technologies, simulated performance tests are conducted to collect user feedback and continuously refine the design. Furthermore, an online platform is established to encourage users to share their usage experiences, fostering positive interactions that provide ongoing inspiration and impetus for continuous product improvement.

4.2. Design Practice and Innovation Points

This project is dedicated to an in-depth study of the restoration of the konghou. Through systematic collection and organization of diversified primary information sources, including but not limited to historical documents, image archives, video recordings, academic treatises, and the practical experience of experts in the replication of ancient musical instruments, a comprehensive research foundation has been established. On this basis, the project employs scientific methods to conduct preliminary logical deduction and hypothesis formation regarding the dimensions, contours, fine details, and functional characteristics of the konghou, ultimately inferring that its core structural components should include a phoenix-head ornament, neck connection, tuning mechanism, stringing system, resonant box, and bridge, among other key parts.

To further validate these hypotheses, the project enters an experimental verification phase, involving the manual creation of a full-scale, high-precision konghou model. This

model integrates principles of ergonomics to ensure practical usability and comfort. Simultaneously, advanced digital modeling techniques are utilized to build a three-dimensional virtual model of the konghou, allowing for spatial layout and structural rationality checks within a digital environment to refine the design. Based on the precise data from digital restoration, the project employs advanced machining technologies for physical production, achieving precise replication of each component. The finished parts undergo

meticulous assembly, lacquering, installation of strings and tuning pegs, and professional tuning procedures, culminating in the complete restoration of the konghou, resulting in a reproduction that is both faithful to the historical prototype and capable of performance. This process exemplifies the depth and breadth of interdisciplinary research, showcasing the unique charm of combining traditional craftsmanship with modern technology.

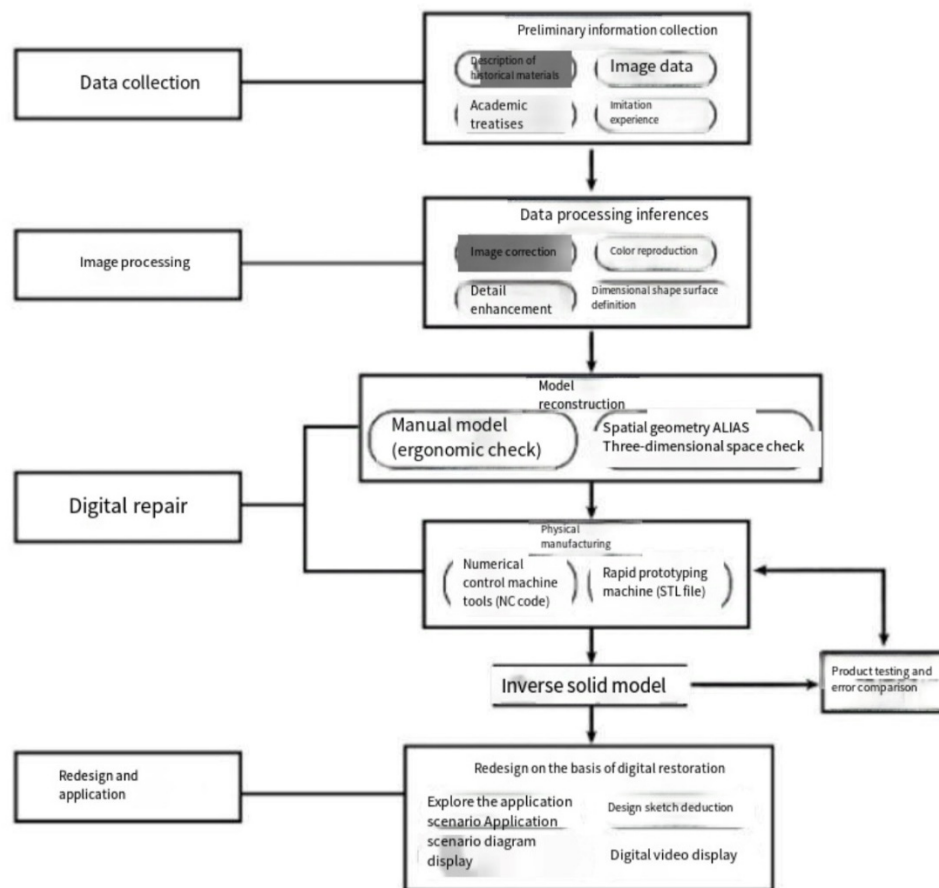


Figure 3. Analysis of the Digital Restoration Process and Methods

5. Chapter 5 Conclusion and Prospects

From the perspective of product design, this paper successfully restored and redesigned the konghou depicted in the murals of Mogao Grotto No. 465 through digital image processing, 3D modeling, and modern design concepts. This approach offers a new pathway for the digital preservation and transmission of cultural heritage and facilitates the integration of traditional culture with contemporary design. Looking to the future, the development of technology and design will further promote the dynamic inheritance and innovative utilization of cultural heritage.

This study not only contributes to the preservation and dissemination of cultural relics but also sets a precedent for leveraging advanced technologies in the exploration and reinterpretation of traditional elements within a modern context. As technology continues to evolve, it will undoubtedly play a pivotal role in bridging the gap between

past and present, ensuring that the cultural treasures of our ancestors remain vibrant and relevant in today's world. The interdisciplinary nature of this research underscores the potential for collaborative efforts across fields to enhance our understanding and appreciation of cultural heritage, thereby securing its place in the fabric of contemporary society.

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