

Feasibility Analysis of Game Design Based on Blue and White Porcelain Plate Restoration

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Abstract: This paper explores the application of interactive game design thinking in the restoration of blue and white porcelain plates and its innovative contribution to cultural heritage conservation. By integrating virtual restoration technology, modern game technology, and cultural inheritance, this study analyzes how game design can enhance the interactivity, engagement, and educational value of the restoration process. The paper first reviews the history and development of cultural heritage restoration, discussing the technical, cultural, and ethical challenges faced in the field. It then proposes that the introduction of game interaction thinking can provide new solutions for heritage restoration. Using the restoration of blue and white porcelain plates as a case study, the paper explores how games can simulate real restoration processes, leveraging technologies such as graphic rendering, digital modeling, virtual reality, augmented reality, and artificial intelligence to allow players to experience the complexities of restoration in a virtual environment, thereby enhancing their skills and understanding of heritage conservation. Finally, the paper analyzes the unique value and challenges of game interaction thinking in heritage restoration and discusses future research directions.

Keywords: game interaction thinking, blue and white porcelain plate restoration, virtual restoration technology, cultural heritage conservation, public engagement

1. Introduction

Cultural heritage restoration is a core task of heritage conservation, aiming to restore the physical form of artifacts while preserving their historical and cultural value. With the advancement of technology, modern techniques such as 3D scanning and digital modeling have been gradually introduced into the field of restoration to improve accuracy and efficiency. However, traditional restoration methods typically rely on expert skills, with low public engagement, limiting the impact of restoration work in cultural dissemination and education.

In recent years, game design has been recognized as an innovative educational tool with interactivity, immersion, and entertainment value. Introducing game interaction thinking into heritage restoration not only enhances engagement in the restoration process but also effectively disseminates cultural knowledge and fosters a sense of responsibility among the public for heritage conservation.

This paper explores the application of game interaction thinking in the restoration of blue and white porcelain plates, analyzing the feasibility of game technology in the restoration process and

discussing the potential value and challenges of this innovative design in the field of cultural heritage restoration. Through this case study, the paper demonstrates how real restoration processes can be simulated and how modern technologies can enhance both the precision and the enjoyment of the restoration tasks, offering new insights into the future development of heritage conservation.

2. Background and Necessity of Cultural Heritage Restoration

2.1. History and Development of Cultural Heritage Restoration

Cultural heritage restoration, as a key component of heritage conservation, has evolved from a reliance on the experiential knowledge and skills of artisans to a more scientific and standardized restoration approach. Initially, the field lacked systematic theoretical guidance. However, with the vigorous development of related disciplines such as archaeology and art studies, cultural heritage restoration gradually established itself as an independent discipline, and with the introduction of modern technology, it has developed into a specialized field supported by professional technical expertise [1].

In the mid-20th century, especially after the end of World War II, significant advancements in both technology and theory were made in the field of cultural heritage restoration. Western countries pioneered the concept of the “principle of minimal intervention,” which advocates for preserving the original state of artifacts as much as possible during restoration, while ensuring that their historical and artistic value is maintained. With the introduction of advanced technologies such as computer technology, laser cleaning, and 3D scanning, restoration work has benefited from modern scientific techniques that enhance precision and efficiency [2].

China’s heritage restoration efforts became aligned with international standards in the 20th century. Particularly after the Cultural Revolution, heritage restoration gradually revived and entered a path toward modernization. Since the 1980s, China has introduced modern restoration technologies and actively engaged in international exchange and collaboration in the field of cultural heritage conservation to further advance restoration techniques [3]. The core goal of cultural heritage restoration is not only to restore the physical form of artifacts but also to ensure the proper protection of their historical, cultural, and artistic values. During the restoration process, experts must adhere to the “principle of minimal intervention” to avoid over-restoration and preserve the historical authenticity of the artifact. At the same time, the materials and methods used must be scientifically sound to achieve both physical restoration and cultural inheritance [4].

2.2. Existing Issues in Cultural Heritage Restoration

Cultural heritage restoration faces multiple challenges in practice, including technical, cultural, and ethical issues, which not only affect the restoration outcomes but also present challenges for the overall development of heritage conservation.

First, technical issues are central to restoration work. The damage to cultural artifacts is often accompanied by material aging and deterioration. Restorers must ensure that the restoration materials used are compatible with the original artifact and have long-term durability. The choice of restoration materials and the precision of restoration are crucial; any deviation could affect the historical authenticity of the artifact. Due to the physical and chemical differences between the restoration materials and the original artifact, the restoration effect is often unstable and could even damage the artifact. Repairing complex damages often presents material-matching challenges, making restoration work even more difficult.

Second, the cultural aspect of heritage restoration cannot be ignored. Cultural artifacts are not merely physical objects but carry rich historical and cultural information. Restoration work not only aims to restore the physical form but also needs to retain the historical and cultural value of the artifact

while ensuring the restoration's effectiveness. The main challenge for restorers is to balance restoring the physical form with preserving historical and cultural content. Restoration should not be merely a technical operation but a recreation of culture and history, which requires restorers to possess a high level of cultural literacy.

Additionally, the “narrowness” of heritage restoration poses difficulties. Due to the complex techniques and specialized knowledge involved, only a small number of professionals can engage in heritage restoration, which leads to a low public awareness of the restoration process. Ordinary people have limited understanding of the restoration process and find it difficult to participate, resulting in a lack of attention to and awareness of heritage conservation. Although traditional restoration methods can delve deeply into historical culture, their closed nature limits public involvement and the spread of culture [5].

Finally, ethical issues in restoration work are also a long-standing challenge. Restorers must find a balance between technical operation and cultural inheritance, avoiding excessive intervention in the original form of the artifact. Whether to alter certain characteristics of the artifact during restoration involves the restorer's professional ethics and cultural responsibility. How to conduct appropriate restoration while respecting the historical context of the artifact is an important consideration in the restoration process.

These challenges not only limit the development of restoration techniques but also open up space for interdisciplinary innovation. The introduction of game interaction thinking can help break the limitations of traditional restoration and provide innovative solutions, particularly in terms of enhancing public participation and cultural awareness.

3. Introduction of Game Interaction Thinking

In the process of cultural heritage restoration, the integration of technology and art is central to the restoration work, and the introduction of game interaction thinking brings a fresh perspective to this process. Through gamified design thinking, we can make cultural heritage restoration more intuitive and engaging while enhancing public awareness and involvement in heritage conservation through interactivity and immersion.

3.1. Overview of Game Technology

Game technology encompasses various fields, including graphics rendering, digital modeling, physics engines, virtual reality (VR), augmented reality (AR), and artificial intelligence (AI). These technologies provide innovative solutions to the field of cultural heritage restoration, significantly enhancing the immersion and interactivity of games, while also introducing new thinking to the restoration process [6].

Graphics rendering technology enables the precise reproduction of artifact details, assisting restoration experts in examining and repairing damaged parts of cultural heritage in a virtual environment. Digital modeling, aided by 3D scanning technology, transforms physical artifacts into digital models, making restoration operations more accurate. Users can experience the restoration process realistically even without direct contact with the physical object [7].

The physics engine simulates physical phenomena in the real world, including gravity, friction, and collisions. In cultural heritage restoration, physical simulation technology can reproduce the physical behavior of restoration materials, helping restorers better understand the potential effects of various materials used in restoration [8].

Virtual reality (VR) and augmented reality (AR) technologies bring an immersive experience to cultural heritage restoration work. With VR, users feel as though they are present at the restoration site, enhancing the intuitiveness of the operation. AR technology integrates virtual restoration tasks

with the real world, enabling users to more clearly understand the restoration process and the true condition of the artifacts. These technologies greatly enhance the interactivity and enjoyment of the restoration experience.

Artificial intelligence is widely used in games, particularly in areas such as task guidance, feedback mechanisms, and difficulty adjustment. In the context of cultural heritage restoration games, AI can provide players with intelligent restoration suggestions and adjust the difficulty of tasks based on restoration outcomes, ensuring players gradually improve their restoration skills. Additionally, AI can analyze player actions and provide personalized feedback, enhancing both the interactivity and educational value of the restoration process.

Game technology, through methods such as graphics rendering, digital modeling, physics engines, VR/AR, and AI, offers scientific, precise, and interactive support for cultural heritage restoration, providing new directions for heritage conservation and cultural dissemination.

3.2. Application and Challenges of Game Technology in Cultural Heritage Restoration

From the previous discussion, we have analyzed the current game technologies, including graphics rendering, digital modeling, physics engines, virtual reality (VR), augmented reality (AR), and artificial intelligence (AI). These technologies provide strong support for cultural heritage restoration, not only improving the precision of the restoration process but also enhancing its enjoyment and educational value through gamified interactive design.

However, despite the numerous innovative methods introduced by game technology in the field of cultural heritage restoration, several challenges remain. First, although virtual restoration platforms can accurately reproduce the damaged state of artifacts, further practical verification is needed to ensure that the restoration process in the game aligns with real-world restoration standards. Second, although physical simulation technology can model the behavior of restoration materials, it still has limitations in simulating the complexity and long-term effects of real restoration materials. Finally, ensuring that the game remains engaging while meeting the stringent requirements of cultural heritage protection is an area that requires further research [9].

Nevertheless, the advantages of game technology in cultural heritage restoration remain prominent. Through VR and AR technologies, players can immerse themselves in the restoration process, deepening their understanding of the historical and cultural value of artifacts. Moreover, task systems and interactive restoration steps enable non-professional players to easily participate in restoration tasks, thereby enhancing public awareness and involvement in heritage conservation.

These technologies and design concepts will be specifically reflected in the following chapters, particularly in the practical case of blue-and-white porcelain plate restoration. We will explore how these game technologies can be applied to the restoration of blue-and-white porcelain plates, address technical and cultural challenges, and evaluate their feasibility and effectiveness in actual restoration work. Through this case study, we will further understand how game interaction thinking can bring innovative solutions to the field of cultural heritage restoration.

4. Feasibility of Game Interaction Thinking in the Restoration of Blue-and-White Porcelain Plates

In the context of blue-and-white porcelain plate restoration, the introduction of game interaction thinking provides innovative ideas for traditional restoration methods. Through virtual restoration technology, players can not only experience the complexity of the restoration process but also, through interactive design, gradually master the skills of artifact restoration. This approach, which combines technology with entertainment, not only enhances the participatory nature of restoration work but also offers the public a brand-new platform for restoration experience.

4.1. Technical Feasibility Analysis

In the restoration of blue-and-white porcelain plates, game interaction thinking, combined with modern technologies such as physics engines, virtual reality (VR), augmented reality (AR), graphics rendering, digital modeling, and artificial intelligence (AI), provides innovative solutions.

Graphics rendering and digital modeling technologies offer precise visual support for the restoration of blue-and-white porcelain plates. Through digital modeling, the game can transform actual artifacts into three-dimensional digital models, allowing players to view every detail of the porcelain plate in a virtual environment, including cracks, missing parts, and material structures. Graphics rendering technology ensures that these details are presented with high precision, enhancing the visual effect and immersion of the game. With this technological support, players can accurately understand the damage to the porcelain plate and receive realistic feedback during the restoration process.

The physics engine simulates the behavior of different restoration materials during the process, ensuring the scientific accuracy of the restoration. For example, when restoring fragments of a blue-and-white porcelain plate, the physics engine simulates the hardness of different restoration fillers and their compatibility with the porcelain shards. If the player chooses a harder restoration material, it might result in a loose fit at the repair site, affecting the overall restoration effect; conversely, selecting a softer material may better conform to the porcelain but could result in an unstable restoration. Through these simulations, players can better understand how material choices impact the restoration and improve their restoration skills.

VR and AR technologies allow players to more intuitively engage in restoration operations. With VR technology, players can observe every detail of the blue-and-white porcelain plate in the virtual environment and restore it from multiple angles, enhancing the precision of the operation. AR technology overlays virtual restoration steps onto the real world, allowing players to view restoration effects through their phones or AR devices, thus enhancing the interactivity and intuitiveness of the restoration. This immersive experience makes the restoration process more vivid and helps players better understand artifact restoration [10].

Artificial intelligence (AI) technology provides players with personalized restoration advice and adjusts task difficulty based on restoration outcomes. AI assesses the accuracy of operations in real-time, offering feedback and suggestions for improvement according to the player's restoration progress. For example, if the player uses inappropriate materials or overcorrects during the restoration process, the AI system provides real-time feedback to help the player adjust their strategy for better results. This intelligent support effectively enhances the player's restoration skills and gradually challenges them with more complex restoration tasks.

Interactive interfaces and feedback mechanisms are key elements for ensuring the precision of restoration tasks. In the design of the blue-and-white porcelain plate restoration game, the operation interface is designed to be simple and intuitive, allowing players to easily select appropriate restoration tools and materials and execute the relevant tasks. For instance, when restoring damaged patterns, players must select the correct brush and color through the virtual interface, adjust the stroke's intensity and delicacy, and master detailed restoration techniques, simulating the precise restoration process in reality. Crucially, the feedback mechanism evaluates the player's restoration effectiveness in real-time and provides guidance. After completing a restoration task, the system will assess the accuracy of the restoration, offering feedback and suggestions for improvement. For example, when restoring cracks, the system evaluates the alignment of the joints, the hardness of the filler material, and the completeness of the pattern restoration, providing the player with ratings and adjustment advice. This instant feedback mechanism encourages players to continuously improve their restoration skills, gradually moving towards a perfect restoration outcome.

4.2. Game Restoration Process and Technical Implementation

In real-life restoration, the process of restoring a blue-and-white porcelain plate typically includes the following steps:

(1) **Artifact Analysis:** The restorer first uses tools such as microscopes and X-rays to examine the damage to the porcelain plate in detail. This helps understand the material, extent of damage, and suitable restoration methods.

(2) **Cleaning:** The restorer uses professional cleaning tools to remove stains and contaminants from the surface of the porcelain plate to prevent further damage.

(3) **Joining and Filling:** Based on the damage, the restorer selects appropriate filling materials (e.g., animal glue, plaster) for joining and filling missing parts.

(4) **Surface Treatment:** The restored porcelain plate is painted or polished to restore its original appearance and ensure its appearance matches its historical style.

(5) **Reinforcement and Protection (Aging Effect):** After restoration, the restorer uses a reinforcing agent to protect the artifact and ensure its long-term preservation, while also creating an aged effect [11][12].

In the game, the restoration process of the blue-and-white porcelain plate should not only retain the basic structure of real-life restoration but also integrate interactivity and educational aspects. This allows players to experience the complexity of restoration in a virtual environment and master the relevant skills. The game's design simulates each step of the real-life restoration process while enhancing interactivity and immersion through modern technology.

First, after entering the game, players will use virtual devices (e.g., microscope, X-ray, CT scan) to conduct a detailed analysis of the blue-and-white porcelain plate. Using graphics rendering and digital modeling technologies, players can accurately observe the cracks, missing parts, and material structure of the plate. This stage, supported by three-dimensional models, helps players fully understand the extent of the damage, providing a basis for decision-making in subsequent restoration steps.

Next, players can begin the cleaning phase of the restoration. At this point, the game uses a physics engine to simulate the physical behavior of restoration materials. Players need to choose the appropriate cleaning method based on the material of the porcelain plate, such as wet cleaning or micro-powder cleaning. The game offers real-time feedback to help players understand the scientific principles behind the cleaning process and ensure that the selected restoration materials meet the plate's preservation requirements.

In the joining and filling stage, players must select the appropriate restoration materials (e.g., glue or fillers) and perform precise joining operations based on the restoration task. The physics engine determines the compatibility and strength of different materials during the restoration process, helping players understand the impact of material selection on the restoration outcome. Additionally, players can observe the repair effect from multiple angles using VR technology, further enhancing the precision and immersion of the restoration operation. Furthermore, AR technology allows players to overlay the virtual restoration steps onto the real-world environment, making the restoration process more intuitive and interactive [13].

In the surface treatment and beautification phase, players must select suitable paints and tools to restore the patterns. Using graphics rendering technology, the game ensures the accurate presentation of colors and textures, allowing players to precisely control the stroke's intensity and delicacy, making the restored porcelain plate as close as possible to the original style. Real-time feedback is provided at each step to ensure that the restoration meets the desired standards.

Finally, AI technology in the game provides personalized suggestions and feedback at every stage of the restoration process, helping players adjust their restoration strategy. AI evaluates the accuracy

of operations in real-time based on the player's progress. If players use inappropriate materials or overstep during the restoration, the system will prompt and suggest more suitable methods. The inclusion of AI makes the restoration tasks more intelligent, ensuring that players achieve the best possible results at every stage.

Upon completion of the task, players can display their restored blue-and-white porcelain plate in a virtual museum, with historical commentary and before-and-after comparisons of the restoration. Through this showcase, players can not only see the changes made during the restoration but also gain a deeper understanding of the cultural background and technical requirements involved in the restoration process [14]. The following figure shows the real-life restoration process and the game's technical design process for restoration.

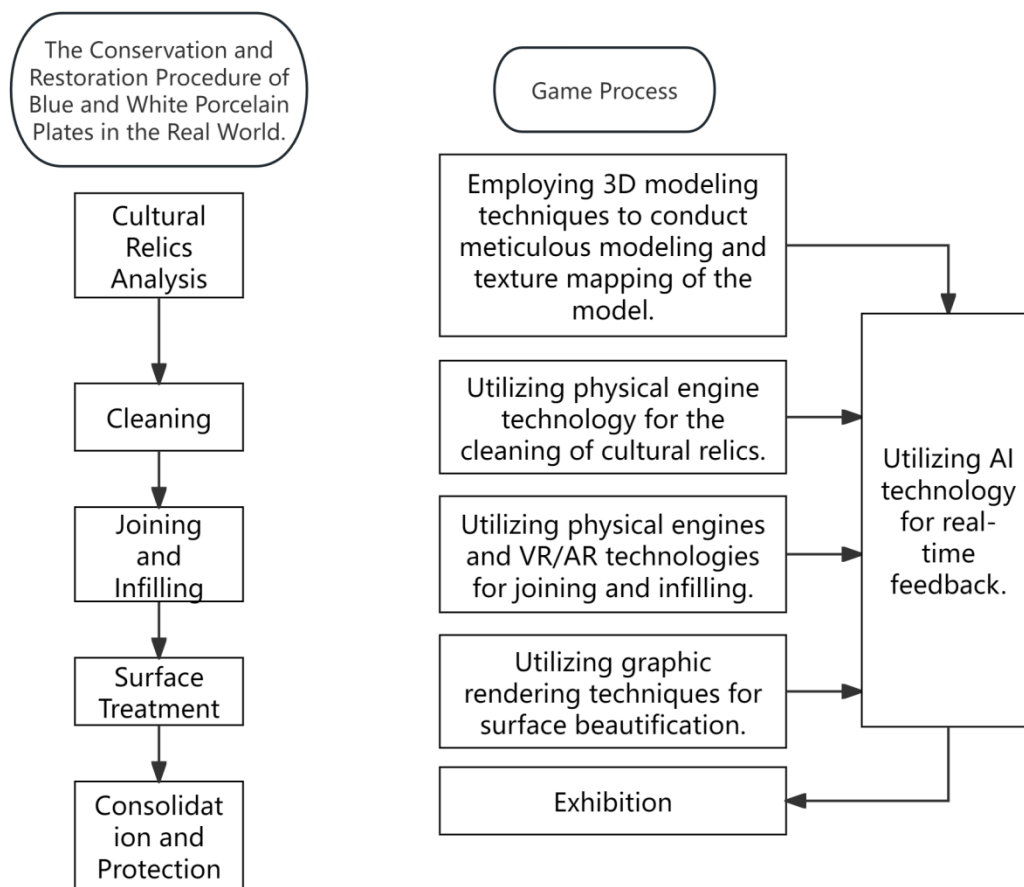


Figure 1: The Production Process of Blue and White Porcelain Plates in Games and Reality

4.3. The Significance of Game Interaction Thinking in the Restoration of Blue-and-White Porcelain Plates

The introduction of game interaction thinking in restoration operations not only provides innovative technical support but also demonstrates its unique role in the fields of culture and education. By constructing highly interactive restoration games, players can experience the intricacy and complexity of the restoration process, while deepening their understanding of cultural heritage conservation and cultural inheritance throughout the game.

As a typical representative of traditional Chinese culture, blue-and-white porcelain embodies profound historical and artistic value. The game design allows the historical background, production

techniques, artistic styles, and other cultural knowledge of blue-and-white porcelain to be integrated into the restoration process. The clever presentation of task systems and background stories allows players to gradually master the origins, development, and characteristics of artistic styles from different historical periods while performing restoration tasks. For example, during the restoration process, players will receive informative prompts about the origins of blue-and-white porcelain, its production process, and the evolution of different artistic styles, thus deepening their understanding of the cultural background behind each restoration task. This method not only allows players to acquire skills during the restoration process but also provides an in-depth study of the traditional craftsmanship and artistic value of blue-and-white porcelain, thereby enhancing their recognition and emotional connection to traditional Chinese culture. At the same time, the restoration process is not only a technical operation but also an emotional experience. Through emotional design, the game guides players to gradually form an emotional bond with the cultural relics as they restore the blue-and-white porcelain plate. Starting with simple restoration tasks, players will gradually appreciate the cultural value and historical significance behind the porcelain. As the restoration work progresses, players will feel an increasing sense of responsibility toward the preservation of cultural relics. This emotional resonance not only enhances the educational value of the game but also stimulates players' sense of responsibility for cultural heritage conservation, encouraging them to actively participate in heritage preservation efforts outside of the game and understand its far-reaching significance.

The gamified restoration process makes the restoration techniques more accessible, especially for players with no prior background in restoration, offering a low-barrier learning platform. Through interaction and practice, players can gradually master restoration techniques. During task completion, they will experience the challenges and complexities of the restoration process, which enhances their hands-on abilities while improving their understanding of restoration techniques. Through the game, players are no longer passive observers but active participants, becoming "restorers" of cultural relics. This widespread learning platform allows more people to engage with the field of cultural heritage restoration, especially those who typically do not have access to traditional craftsmanship. The game offers an easy and enjoyable entry point. Furthermore, the game enhances players' social responsibility for cultural heritage protection by improving their restoration skills. In the game, players understand the details and challenges of the restoration tasks and realize that restoration is not merely a technical operation but also a means of safeguarding the history and culture of cultural relics. Through these tasks, players gradually understand that cultural heritage preservation is not just the responsibility of professional restorers but also a collective responsibility of all members of society. This combination of education and emotion makes heritage conservation not only a matter of imparting restoration skills but also furthers public awareness and engagement with cultural heritage preservation.

5. Conclusion

This paper explores the feasibility of applying game interaction thinking to the restoration of blue-and-white porcelain plates and analyzes how virtual restoration technologies can enhance the interactivity, engagement, and educational value of the restoration process. By integrating modern technologies such as graphic rendering, digital modeling, physics engines, virtual reality (VR), augmented reality (AR), and artificial intelligence (AI), games not only make the restoration process more vivid and interesting but also help players better understand the complexities and cultural value of heritage conservation. Through this innovative approach, games break down the closed nature of cultural heritage restoration, allowing more non-professionals to participate and enhancing public awareness of cultural heritage preservation.

However, despite the numerous advantages that game interaction thinking brings to cultural heritage restoration, the precision and authenticity of virtual restoration technology remain a

challenge. In the restoration process, ensuring that virtual restoration operations can accurately replicate the historical appearance of cultural relics and that each restoration step adheres to real-world heritage conservation standards still requires further improvements in technology precision. Additionally, the historical accuracy and artistic integrity in game design need to be carefully managed to avoid oversimplification or entertainment-driven adaptations that could dilute the cultural depth of the restoration. Future research could expand to the restoration of other types of cultural relics, such as sculptures, architecture, and ancient books, which face different technical and cultural challenges in their restoration. How to design personalized games based on the unique characteristics of these relics will be a key focus for future research.

As the cultural industry and digital technology continue to merge, interdisciplinary collaboration has become a crucial factor in advancing restoration technologies. Effective cooperation between fields such as cultural studies, history, game design, and technology will offer more innovative solutions for heritage conservation, enhancing restoration techniques and providing new ideas for the sustainable preservation of cultural heritage. Game interaction thinking is not only a technological innovation but also provides new paths and practical approaches for heritage preservation, especially in terms of increasing public participation and cultural awareness, which holds significant importance.

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