

## *Retraction*

# **Retracted: Virtual Reality-Based Digital Restoration Methods and Applications for Ancient Buildings**

### **Journal of Mathematics**

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] T. Wang and L. Zhao, "Virtual Reality-Based Digital Restoration Methods and Applications for Ancient Buildings," *Journal of Mathematics*, vol. 2022, Article ID 2305463, 10 pages, 2022.

## Research Article

# Virtual Reality-Based Digital Restoration Methods and Applications for Ancient Buildings

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At a time of rapid technological development, 3D stereoscopic images and virtual reality technology are being used in art and design, as well as in the digital conservation of ancient buildings and their restoration. Virtual reality art is a high degree of integration between art and digital technology and is a new form of digital art. As a means of presenting architectural art, digital restoration of ancient buildings is a form of expression that combines knowledge, art, and technology. The digital restoration of ancient buildings and the creation of a 3D interactive display system are of great value for the realization of real space and the preservation of ancient sites. In this paper, we design a system that combines 3D stereoscopic and virtual reality technologies for the restoration of ancient buildings. Through the research and practice of this system, it can be translated into relevant design application research in other art and design fields, which is of great practical significance for future virtual reality expansion space.

## 1. Introduction

The cultural heritage of ancient buildings carries a deep historical and cultural heritage [1], witnessing a city's stormy history over thousands of years. The unique style and rich cultural connotations of ancient buildings are the inheritors of traditional culture [2] and superior craftsmanship, the crystallization of the wisdom of the ancients. With thousands of years of history and civilization, the ancients have created immortal legends with their hands, and their understanding and creation of the art of architecture in particular has highlighted the characteristics of different civilizations [3]. However, the cultural heritage of ancient buildings cannot be immortalized and is not renewable and is constantly subject to the erosion of the natural environment and the destruction of human activities in the course of history [4]. It has been subjected to natural and human activity over the course of history [5]. All we can do is to preserve it, to slow down its demise, and to pass on its spirit. As people become more aware of the importance of the cultural heritage of ancient buildings, it is important to

preserve it for as long as possible without damaging the buildings themselves. The importance of preserving the cultural heritage of ancient buildings without damaging the buildings themselves is particularly important [6].

Digital restoration of ancient buildings as a means of presenting the art of ancient architecture is a form of expression that combines knowledge, art, and technology [7]. With the development and enhancement of information technology, 3D stereoscopic image technology [8] and virtual interactive technology [9], the digital means of ancient architecture restoration animation digital transformation and innovation, built 3D stereoscopic effect of virtual interactive ancient architecture restoration display system, for the real space to achieve the display, the preservation of ancient architectural sites is of great importance. It is of great importance to protect ancient architectural sites. Well-preserved physical antiquities play a realistic role in demonstrating the historical process, architectural style, and human life [10]. However, damaged or corroded parts of ancient buildings are unable to demonstrate this cultural need to the world [11]. This is an incomplete presentation of

ancient architecture and culture as a whole. According to a certain phenomenon, ancient buildings that cannot be restored to their true proportions are supplemented by digital forms. Improving the full picture of ancient buildings is of great significance to human understanding of the history and culture of ancient buildings, their architectural patterns, and human life [12]. It will also be a forward-looking initiative.

In terms of application technology, 3D stereoscopic and projection technology and virtual reality (VR) interactive technology have been developed and applied to different fields of art [13]. For example, 3D stereoscopic and projection technology is being used in film industry today, and virtual interaction technology is being used successfully in online games. However, there has been very little research into combining the two together in one field. The reason is that, first, the development of technical procedures is complicated, and the investment of capital and equipment is high; second, the application carrier is not suitable, and people are not yet fully aware of the value and prospect of combining 3D stereoscopic and projection technology with virtual reality interactive technology in the same field. The digital restoration of ancient buildings is the best vehicle for the application of this technology [14], and it also provides a new technology and means for the artistic expression of the restoration of ancient buildings.

In response to the aforementioned technique, this paper presents a practical design and theoretical study of the application of 3D stereoscopic technology and virtual reality to the digital restoration of ancient buildings. The research mainly includes the design of ancient building structure reproduction, 3D stereo image production, and virtual reality interactive technology, as well as the combination of the two-application technology and multi-channel stereo projection system application. For many years, people have wanted to experience the real experience of roaming through ancient buildings. Three-dimensional stereoscopic technology combined with virtual reality technology applied to ancient architecture restoration animation will enable the viewer to have the experience of roaming through the disappearance of ancient buildings, experience the construction style of ancient buildings, and the history and culture of ancient buildings. In the coming section, the related technologies are discussed in much detail, such as virtual reality and architecture restoration animation. Moreover, the design of model and production techniques for ancient buildings is also discussed. Section 3 proposed the design of a system for interactive three-dimensional effect technology. Section 4 presents the explanation of development and realization of three-dimensional virtual reality technology in the digital restoration of ancient buildings. Section 5 is the conclusion section.

## 2. Related Technologies

**2.1. Virtual Reality.** Virtual reality (VR) is a high-tech tool that has emerged in recent years and is mainly used in the design of displays [15, 16], also known as aurora technology

or artificial environments. VR is an integrated and comprehensive technology that involves computer graphics, human-computer interaction technology, sensing technology, artificial intelligence, and other fields. It uses computer-generated software to generate realistic three-dimensional images, with senses such as hearing, touching, and smelling to enable the experimenter to naturally experience and interact with the constructed virtual world. For example, the computer immediately performs calculations when the participant moves position or changes gestures, causing the 3D world image to move or change to create a sense of presence. The technology integrates the latest developments in computer graphics (CG) technology, simulation technology, sensing technology, artificial intelligence, display technology, network parallel processing, and other technologies and is a high-tech simulation system generated with the aid of computer technology.

In a nutshell, virtual reality is a new way for people to manipulate and interact with computer data through visualization. Compared to traditional human-computer interaction, virtual reality has made a qualitative leap forward in terms of technology and ideas. "Virtual reality" is a computer-generated medium. The term "reality" refers to anything or environment that exists in the world in a physical or functional sense. It can be practically realizable, practically unrealizable, or simply unrealizable. Thus, virtual reality refers to a computer-generated environment in a new medium, that is, a simulated, fictitious environment. A person can place themselves into this environment using various special devices and achieve manipulation, control of the environment, and achieve special purposes, that is, the person is the master of this environment.

**2.2. Architectural Restoration Animation.** Architectural restoration animation refers to the use of computer three-dimensional technology to produce animation works about the appearance of ancient buildings [17, 18] and is an important means of digital restoration of modern ancient buildings. Figure 1 shows a 3D restoration of the old Summer Palace site. Surface modelling is one of the most important directions of three-dimensional geometric modelling, which refers to the display of a surface on a computer through modelling and the interactive display and processing of its parameters.

Surfaces can be represented in two ways, nonparametric surfaces and parametric surfaces. Nonparametric surfaces, also known as functional surfaces, refer to surfaces that are described by surface equations over a defined range of domain values and can be expressed as

$$Z = f(x, y). \quad (1)$$

In determining the boundary of the domain of the function surface, the boundary equation  $y = g(x)$  is constructed to limit the interval of variation of  $x$ , so that  $x$  and  $y$  vary gradually in fixed steps within the boundary, which in turn operates the coordinate values corresponding to each grid point on the surface, resulting in a grid model of the function surface.



FIGURE 1: The 3D restoration of the old summer palace.

**2.3. Model Design and Production Techniques for Ancient Buildings.** Model building is the basis for completing the digital restoration of ancient buildings [19, 20] and the design of ancient building models should follow the following basic principles:

- (i) Accurate model structure, in line with the cultural characteristics of ancient buildings. The models must be built in strict accordance with the references provided by the documentation and original images. The scenic model must be historically accurate, and the furniture must be in accordance with the actual scale and position of the space design. For ancient buildings, the most difficult aspect to control is the structural interplay, especially as most of the buildings are wooden and brick structures, making the model complex to build. How to restore a realistic scene is the key to modelling.
- (ii) The material mapping is detailed and in line with the sense of chronological history. The restored animation of ancient buildings is a vehicle to disseminate information about ancient culture and to meet the needs of people for increased understanding, awareness, learning, and research of lost monuments. The aim is to increase people's understanding, awareness, learning, and research of the lost monuments. It is important to show a realistic image of ancient buildings. The material requirements for the mapping are a detailed analysis of the original building materials and a detailed mapping of the original architecture.

### 3. Design of a System for Interactive 3D Effect Technology

The technical means of application for the digital conservation of ancient buildings is to digitally produce and exhibit them [21]. The greatest purpose of digital conservation and restoration is to record and pass on history. Many countries and regions are now establishing digital museums and galleries for people to visit and study. With the improvement of modern technology and the transformation of people's needs, the original form of ancient architecture animation show can no longer meet the people's deeper, more thorough and more

intuitive understanding of the disappearance of ancient buildings. People's understanding of ancient buildings is no longer limited to the perception of their physical structure, so 3D technology has revolutionized ancient buildings.

Restoration animation of ancient buildings is different from film and animation art. Its purpose is not only artistic expression and representation but more importantly, documentary and recording. For lost buildings, people want more than to be able to touch and feel them in real life, not as a third-person viewer of a restored animation. The most effective way to achieve this is through the use of virtual interaction technology for these buildings that cannot be authentically restored and reconstructed. By applying 3D technology and virtual interactive technology to the restored animation, although the real sense of touch cannot be realized, it is possible to view and navigate the ancient buildings as the first person in the animation and design the roaming route as you wish, while also feeling the real sense of space of the ancient buildings. A screenshot of the 3D restored image video is shown in Figure 2.

**3.1. System Comparison.** Virtual reality interactive display design for ancient buildings. It is based on the original restoration animation of ancient buildings to achieve 3D stereoscopic effects and interactive experience effects. The aim is to enable the experienter to truly feel the realities of ancient restoration and interactive experience. At the same time, it can solve the current problems of restoration of ancient buildings, such as the problem of land needed for reconstruction, the technical problem of repairing the original appearance, the problem of long repair time cycles, and even the problem of whether many experts hold the need for restoration of ancient buildings that have been lost, as shown in Table 1.

**3.2. Systematic Research Design Thinking Process.** The development of a virtual reality interactive display system for three-dimensional effects of ancient buildings requires five stages, namely market research and demand analysis, system design, technology development and application, operation and testing, and effect evaluation as shown in Figure 3.

The system is designed to achieve the following functions:



(a)

(b)

FIGURE 2: (a) Screenshot from the Dunhuang Mogao Grottoes 3D restoration video—red and blue technology. (b) Screenshot from the Dunhuang Mogao Grottoes 3D restoration video—polarization technology.

TABLE 1: Virtual reality interactive display design system for building body effects in antiquity.

Comparison of virtual reality interactive display systems for three-dimensional effects of ancient buildings			
	Resource utilization	Means approach	Software operating environment
Predevelopment	Physical or model visual material	Physical or model image display	General computers Projection equipment Physical stations Mainstream servers
After development	Image data system software	Three-dimensional virtual interactive display	Multichannel stereoscopic projection equipment Camera sensing equipment 3D stereo glasses

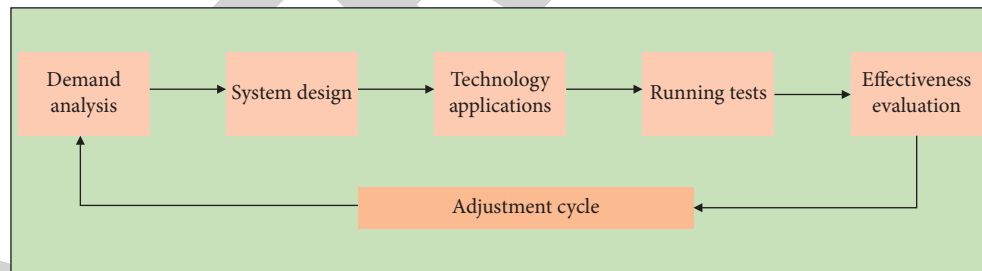


FIGURE 3: Procedures of system design and development.

- (i) 3D visualization of architectural model design and implementation (model design, material UV mapping design, and lighting design)
- (ii) Application of stereoscopic imaging technology
- (iii) Virtual interaction technology design
- (iv) Stereo display technology

A summary of the aforementioned points for the design and development of system can be seen in Figure 4.

**3.3. Technical Programmed Design.** The system is divided into two categories. One is the virtual interactive display design for the 3D effect of ancient buildings on a PC; the other is the virtual interactive display design for the 3D effect

of ancient buildings under multichannel stereoscopic projection. The procedure is the same, but the difference is that the second type is based on the first type with the addition of projection equipment and camera equipment. The control settings are the same as on the PC, except that the mouse directional control is transformed into a character walking motion capture (Figures 5 and 6).

## 4. The Development and Realization of 3D Virtual Reality Technology in the Digital Restoration of Ancient Buildings

**4.1. Realization of the Software Production Process.** We use three parts to describe in detail the interactive design and development process of the 3D effect of ancient buildings.

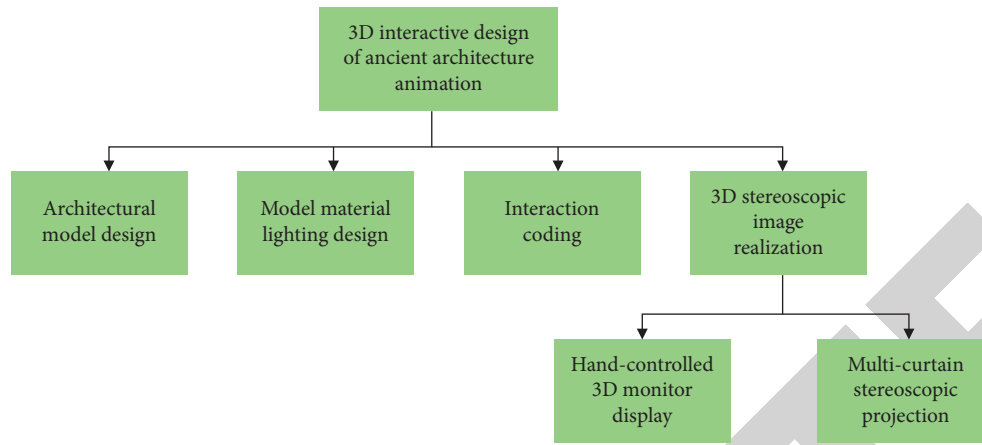


FIGURE 4: Procedures of system design and development.

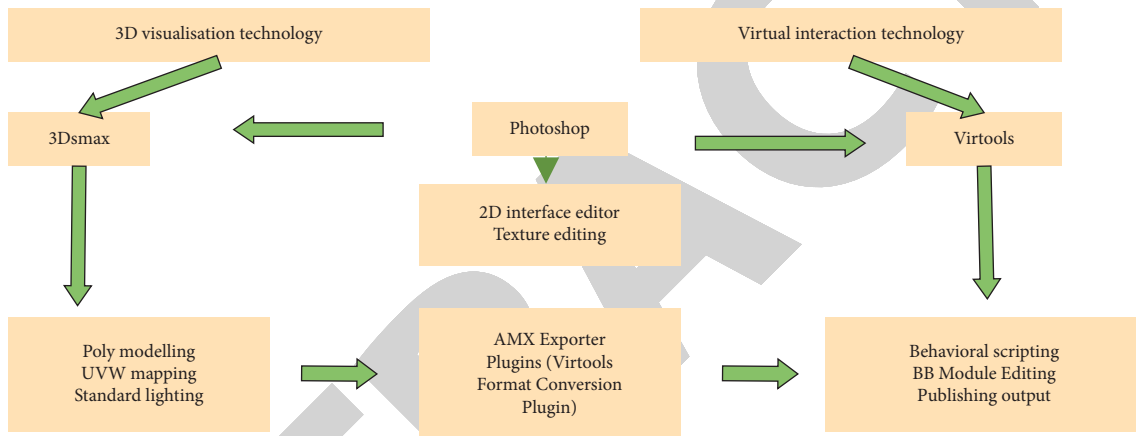


FIGURE 5: A virtual interactive display design to realize the 3D effect of ancient buildings on the PC.

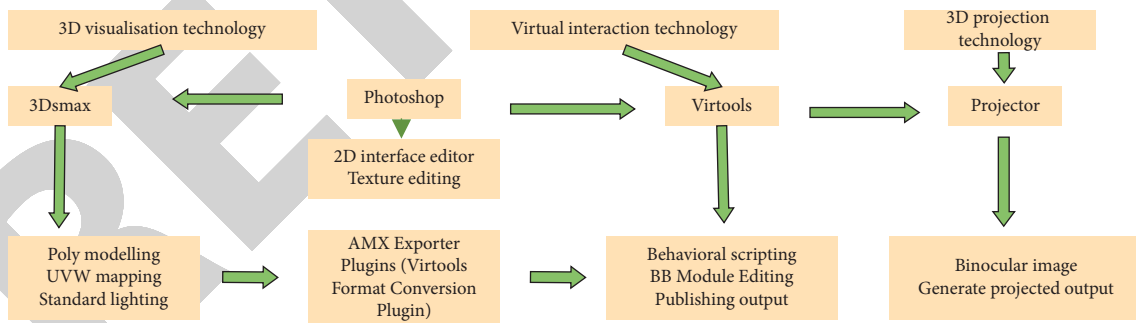


FIGURE 6: Virtual interactive display design to realize the 3D stereo effect of ancient buildings under multichannel stereo projection.

The specific content includes program structure design, resource file design, and specific realization of program difficulties. The software production application flow chart is shown in Figure 7.

#### 4.2. Realization of 3D Visualized Ancient Building Model

4.2.1. Model Design. There are many platforms for visualizing 3D images, and this paper focuses on the field of 3D modelling technology. The 3DS MAX software platform was

chosen for this study because of the variety of exported data types and the stability of the combination with Virtools. The most important part of the digital restoration of ancient buildings is the digitization of the display of ancient buildings, and the prerequisite step for the digitization of ancient buildings is the model, understanding the structure of ancient buildings is extremely important, the fundamental of the restoration of ancient buildings animation is to restore the original appearance of ancient buildings without modification.

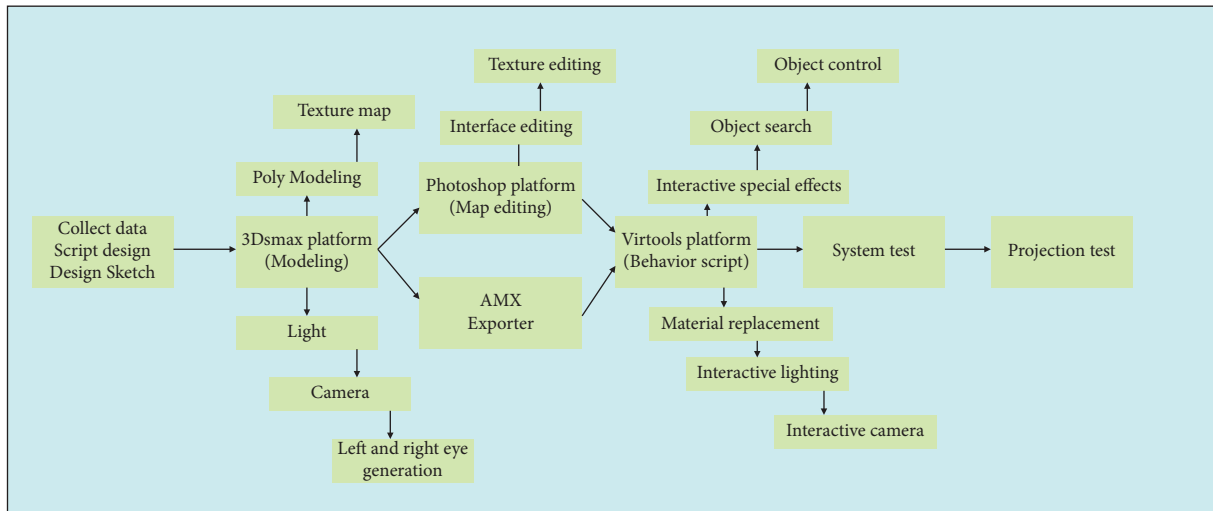


FIGURE 7: Procedures for software production.

The creation of a model of an ancient building generally starts with the geometry, creating box geometry that can be edited, adding lines to the layout based on the general shape of the model, adjusting the divisions, going from whole to partial in a gradual and progressive manner, adding new geometry to create new objects such as tiles, doors, windows, and stone benches if the number of geometry is insufficient. However, the reason for keeping the number of polygonal rows as well as the number of faces to a minimum is to save resources. The problem that also arises is that the model is simplistic and it is not detailed enough. As the model is an architectural model, the model does not produce its own shape changes, allowing for triangular or polygonal surfaces. If you are making a biological model, it is best to ensure that all surfaces are quadrilateral to avoid tearing of the mapping when the object is animated in motion. Once you are satisfied with the model, it is important to focus on the main points and not on everything and to simplify the model outside of the camera and control range. Also give due consideration to the size of the model, the type of material and the cost of production to ensure that art and reality are combined. Figures 8(a) to 8(d) show the process of modelling ancient buildings.

Based on old film, documentation and modern restoration of the building as a reference to create a model of the lost and destroyed parts of the building needed for the restoration animation, the challenge was to accurately represent the complex structural relationships of the ancient building and to control the number of surfaces and lines. The reason for this is that the smaller the amount of data that is transferred to the Virtools software, the better the interaction will be. This depends on the performance of the equipment. This is not normally a consideration if the model is put into operation in a large venue. The eaves and windows are shaped with a return pattern as shown in Figure 9.

**4.2.2. Materials UV Mapping.** The quality of the mapping depends on the quality of the model if you want to give it a realistic feel with a high level of visual spatial enhancement.

The coordinates of 3D space are divided into three axes X, Y, and Z, corresponding to the 3D space mapping coordinates U, V, and W, so the 3Ds Max mapping coordinates are called UV coordinates. In the architectural performance, according to the picture of the distant reality, primary and secondary relationship, detail requirements, generally will use two kinds of editing UV coordinate distribution tools. UVW map is a simple way of unfolding UV and is often used in architecture to create new objects and objects that are not very important in the distance. Unwrap is often used in architecture for old effects and for models in some close-ups and can often be used in distant views, such as a specific shape of stain in a specific position in a corner. The Unwrap mapping is shown in Figure 10, and the finished Unwrap mapping is shown in Figure 11.

**4.2.3. Lighting Design.** For architectural models, the lighting is arranged to create a realistic natural ambient light effect. To create the ideal lighting effect in software, it is necessary to have an understanding of light in nature. In the natural environment, there is only one source of light and that is the sun, whereas light comes from many directions, the reason being that the direct light from the sun is refracted or reflected by certain objects. This constitutes the primary and secondary light. For larger scenes, the building is generally illuminated using a multipoint method: one main light source and several auxiliary light sources, the role of the auxiliary light source is to fill in the light, making the outline of the object clear, while making the building have a contrasting relationship between light and dark without producing large contrasts. This is common in nature and is also done in the software to influence the material bump effect. As shown in Figure 12, the contrast between one light exposure and multiple light exposure is shown.

**4.3. Application and Implementation of Binocular Stereo Imaging Technology.** To create a stereoscopic image, it is important to understand the principles of stereoscopic

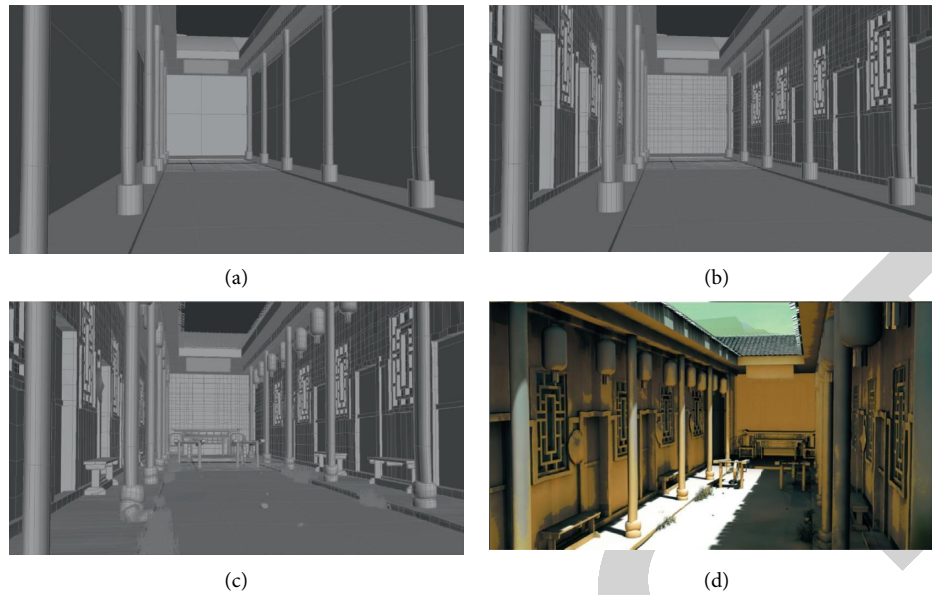


FIGURE 8: (a) Building for foundational model; (b) building for adjustment model; (c) building for modification model; (d) completed rendered model.

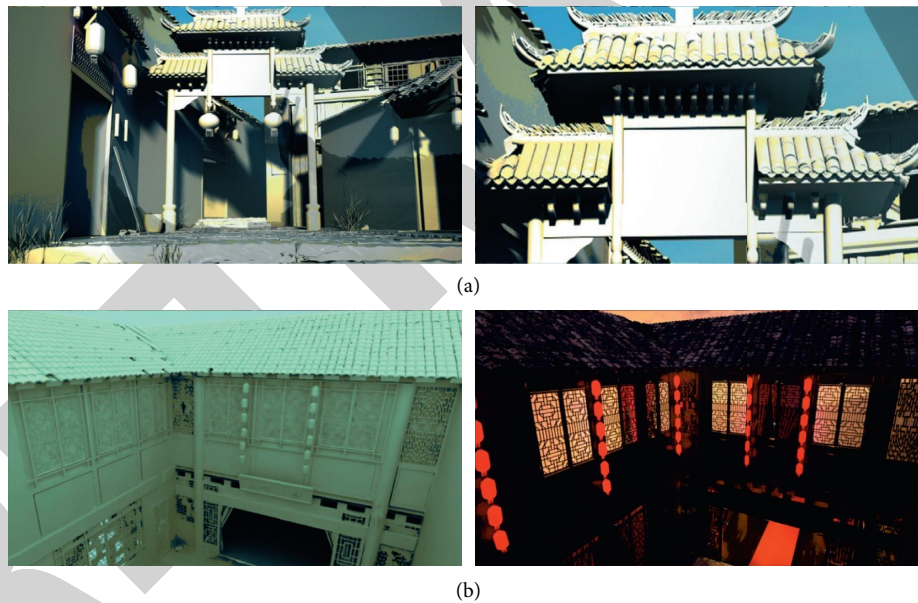


FIGURE 9: (a) Eaves tile modelling and (b) retrospective window molding.

imaging. Since the human eye has a pupillary distance of approximately 65 mm, when people look at an object with both eyes, the left and right eyes each see the left and right sides of the object. The details of the object on the left and right side of the scene are seen by both eyes. This means that two similar two-dimensional images with horizontal parallax are formed on the human retina, and the objects are imaged slightly differently on the left and right retinas. This means that the two two-dimensional images are reproduced with binocular parallax to form a three-dimensional image. We watch the stereoscopic film is to simulate the principle of three-dimensional image formation of the

human eye, the first left and right eyes of the monocular image were recorded, through the projector and the corresponding stereoscopic projection equipment, so that the audience left and right eyes respectively see the corresponding monocular image, and then through the brain reproduced into a three-dimensional image. In technical terms, this means that the left and right double images are projected and reflected in the left and right eyes of the audience respectively. In order to achieve a binocular image, we had to create a binocular virtual camera to capture it. The left and right eye images created by the binocular camera are shown in Figure 13.



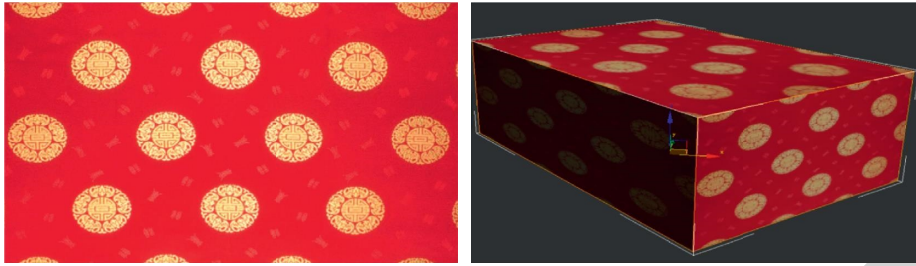
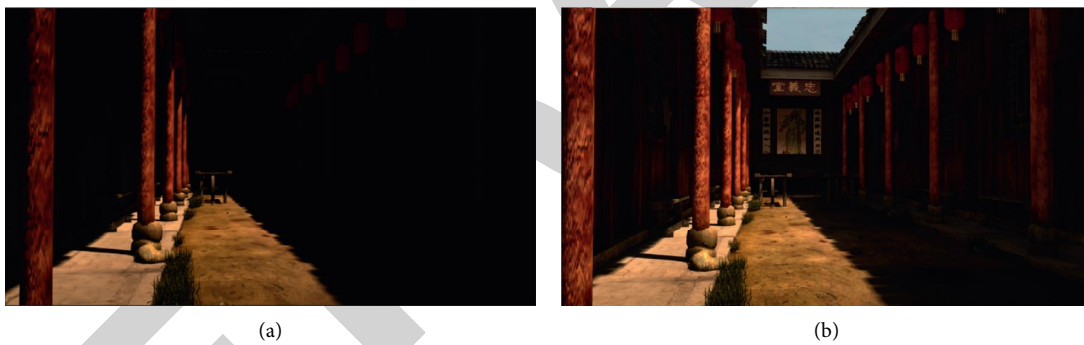


FIGURE 10: UVW map chartlet.



FIGURE 11: Completed unwrap chartlet.



(a)

(b)

FIGURE 12: One light illuminates the building with a high contrast of light and shadow (a); multiple lights illuminate the building with the right contrast of light and dark, making the picture more vivid (b).

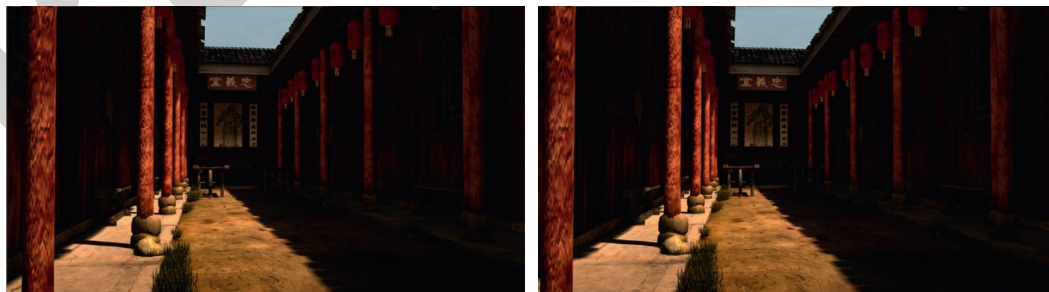


FIGURE 13: Images of the left and right eyes created by the binocular camera, with the left eye sequence static needle image on the left and the right eye sequence static needle image on the right.

**4.4. Virtual Interaction Technology Implementation.** At the final stage of the model's completion, collision control is done on the objects because the model camera can go

through objects, while in real life, we humans cannot go through objects, so we have to do collision control on the photography. This means that the camera simulates the



FIGURE 14: The camera will not advance if it touches a chair.



FIGURE 15: Schematic diagram of the digital restoration of the “Shaolin Temple” building applying the virtual reality approach of this paper.

human eye, the camera moves to simulate the character walking, and when we encounter walls and obstructions we cannot get through objects, so it is more realistic (Figure 14).

#### 4.5. Stereoscopic Display Technology Implementation.

“Stereo vision” is the brain’s satisfaction with the “depth” perception of a stereoscopic image. It is not easy to obtain “depth perception” from the “monocular cues” of traditional flat displays. from the “monocular cues” of traditional flat displays is not easy, the difficulty lies in the habituation of people to two-dimensional images. The difficulty lies in people’s habituation to two-dimensional images. These cues include light and shade, relative size, spatial perspective (or atmospheric perspective), motion parallax (by the movement of a nearby object across the field of view into the field of view), and the perception of depth (a visual cue created by the act of moving a nearby object across the field of view to a more distant object than a distant one), and most importantly (or atmospheric perspective), kinematic parallax (a visual cue created by the act of moving a nearby object across the field of view to a further distance than a distant object) and, most importantly, “occlusion cues” (objects obscured above and below or in front and behind) and perspective. All these influences play a key role in stereoscopic vision.

Virtual reality technology actually provides the viewer’s eyes with two separate images to create a depth perception effect. When viewing a particular object presented by a pair of identical images. Depending on the difference in horizontal distance between the two images (pupil depending on the difference in horizontal distance between the two images

(60 mm pupillary distance), the viewer’s eyes will move to “converge” in front of, above or behind the screen, depending on the situation. But the human brain is always focused on the screen, which creates a sense of unreality, and this unreality is what makes our perception of a stereoscopic scene different from that of the real world. In the real world, the visual focus and convergence of our vision is consistent. This known response is broken when viewing stereoscopic images, and this is what causes the discomfort of stereoscopy. While most people are comfortable with the sudden difference in focus and convergence, some people are more sensitive to seeing stereoscopic images and experience discomfort or dizziness and image confusion. Figure 15 shows a schematic diagram of the digital restoration of the “Shaolin Temple” building by applying the methods in this paper.

## 5. Conclusion

The study of the application of virtual reality interactive technology in the digital restoration of ancient buildings has great application value and practical significance. The method provides a new digital display concept for the restoration of ancient buildings and provides a new virtual presence for the experience. The research is pioneering and highly integrative in the field of digital restoration of ancient buildings, broadening the field of application and interactive experience of virtual reality technology, and providing a very practical and effective means of digital restoration of ancient buildings through the practical development and research of

the project system. In addition, this technology is also very suitable for modern art design and can be applied to figurative design works.

### Data Availability

The data sets used during this study are available from the corresponding author on reasonable request.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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