

Retraction

Retracted: Based on Virtual Reality Technology Research on Innovation and Design of Ceramic Painting Products

Mathematical Problems in Engineering

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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) Peer-review manipulation

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] Y. Jiang, "Based on Virtual Reality Technology Research on Innovation and Design of Ceramic Painting Products," *Mathematical Problems in Engineering*, vol. 2022, Article ID 4421769, 7 pages, 2022.

Research Article

Based on Virtual Reality Technology Research on Innovation and Design of Ceramic Painting Products

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In order to obtain the complete color point cloud data of traditional ceramic artworks and reconstruct them efficiently, a 3D digital reconstruction method of ceramic painting products based on virtual reality technology was proposed. By the method, the 3D color point cloud data of ceramic works were collected by the camera 3D scanning equipment. The new postprocessing methods such as fusion and repair were investigated and proposed so as to obtain the complete optimized color point cloud information. The high-fidelity 3D mesh model and simplified mesh of ceramic artworks were obtained through the mesh process and the digital display platform was developed by using virtual reality technology. The experiment results showed that the 3D color point cloud data of traditional ceramic artworks were obtained by +5 exposure blend methods on average in the 6 combined modes and point cloud optimization and repair were completed. High-precision color mesh model was generated and digital promotion and publicity were carried out. The proposed 3D reconstruction technology and virtual display method made a positive exploration for the protection, inheritance, and promotion of China's ceramic artworks and made a new attempt for the digital protection of cultural heritage by using modern science and technology.

1. Introduction

In the Neolithic period, human beings began to make and use pottery. After thousands of years of development and evolution, glazed pottery gradually emerged. Then, in the feudal society period when human beings mastered fire more skillfully, human beings were able to make ceramics with a more dense molecular arrangement and smoother surface glaze. In the early stage of ceramics development, ceramics were always developed to meet practicality first and then shape and decoration [1]. After the social productive forces gradually met the needs of human basic survival, the functions and application scenarios of ceramics also changed. From their original role as containers, they have developed into objects with ornamental collection value, even for funeral, marriage, and so on. The development of ceramic products design coincides with Maslow's Demand Theory.

People begin to pursue spiritual aesthetic needs when practicality is satisfied. Therefore, the evolution trajectory

of ceramics is determined and dominated by social productivity, human material life, and human spiritual needs [2].

Ceramics design methods are also changing with the changes of social productivity and technology, from traditional manual design to CAD software aided design. With the gradual maturity of VR technology, VR technology has also been applied to the design industry. Nowadays, the application of VR technology in the design industry includes interior, landscape, automobile, aircraft, electronic products, and other fields, but there are still very few cases and practices in the field of ceramics design [3].

Virtual Reality (VR for short) is a new technology in the middle of the twentieth century. This technology is pioneered in the United States. After half a century of exploration and practice in various laboratories and university research institutes, this technology has gradually been mature and gradually entered people's vision in production, entertainment, innovative research, and other aspects.

2. Literature Review

EA Filonova et al. developed SpmAR, a software with a very user-friendly interface for rapid 3D model building [4]. Demidov et al. focused on the visualization research of virtual reality and developed a virtual holographic system, which solved the limitations of current interaction technology [5]. Jijun et al. developed an olfactory simulator, which was a breakthrough in the research of virtual reality technology in the field of olfactory. Once the fruit in the virtual space was placed on the nose tip wearing the olfactory simulator, the user could smell the fragrance of the fruit emitted by the device at the nose tip [6]. Liu et al. provided a virtual reality demonstration environment by integrating distributed virtual environment, as well as a virtual reality system for pilot training, a 3D dynamic database, and a development platform for a virtual reality-based application system. They also focused on the representation and processing of physical characteristics of objects in the virtual environment and developed some hardware for visual interface in virtual reality [7]. Iijima et al. made a further progress in VR technology and found more foothold for the technology, such as education, design, and other fields, giving virtual reality technology more possibilities and greater development prospects [8]. Xu et al. focused their research in VR on the representation and processing of physical characteristics of objects in a VR environment [9]. Bounareli et al. established a desktop virtual building environment real-time roaming system [10]. Xie et al. carried out a 3D reconstruction of the pagoda to protect this world's cultural heritage in a digital form. Moreover, the Palace Museum in China completed the 3D digitalization of many cultural relics and displayed them on the online platform of "Digital Heritage Library," which was open to people to browse the 3D models of cultural relics [11].

In the above-given data acquisition method, 3D location information and surface color information are obtained separately. In the later texture mapping process, due to the influence of human factors, the accuracy of mapping location is inevitably not high, resulting in the matching degree of the 3D reconstruction model and original cultural relics being affected. At the same time, traditional ceramic artworks have their unique attributes, such as the complexity of the model and the high reflective property of the surface glaze, which inevitably leads to data missing and model holes in the data collection. In addition, the richness of the glaze color on the ceramics surface also poses a new challenge to the color reducibility of the 3D reconstruction model surface. On the basis of integrating the current 3D data acquisition technology, the technical route and implementation plan suitable for the 3D digital collection of ceramic cultural relics are proposed. Combined with the color point cloud overlapping algorithm and hole repair algorithm, the complete information reconstruction of ceramic cultural relics is realized. In cooperation with Guangdong Ceramic Museum, data collection of 115 ceramic artworks has been realized by using the proposed technology and methods and the promotion and inheritance of traditional cultural heritage has been innovatively realized by using virtual reality and other information means.

3. Research Methods

3.1. Artistic Features of Ceramics and 3D Reconstruction Scheme

3.1.1. The Artistic Characteristics of Ceramics. Ceramics originated in the late Neolithic Age. After a long period of development and accumulation, ceramics developed rapidly in the Tang and Song dynasties and reached prosperity in the Ming and Qing Dynasties [12]. According to the records, the Ming Dynasty pottery production had been "initially divided into eight processes" and firing technology and product quality were greatly improved. Traditional ceramics artists gave full play to the good plasticity of local clay to create a large number of vivid and modelling complex characters, such as animals, birds, flowers, fruits, and vegetables. They also made use of the plant ash, scrap metal, and jade residue by local people's workshops to produce ceramic glaze, forming a thick dignified, and colorful characteristics [13].

3.1.2. 3D Reconstruction of Ceramics. The first step of 3D reconstruction is to obtain accurate data information. According to the characteristics of ceramics, the best scheme is to obtain the 3D position information and color information of the object at the same time in this stage to ensure the authenticity and accuracy of the collected data. At present, the commonly used noncontact 3D scanning equipment includes laser, structured light, and photographic 3D scanners.

The laser 3D scanner can calculate the spatial information of the object by projecting the laser beam to the object and getting the reflected beam from the receiving sensor. It has the characteristics of a high data sampling rate and high precision. However, the reflectivity of the scanned object is easy to affect the reflection of the laser beam. And, the surface texture, environment, and structure are easy to make the data scanned by laser have a large number of noise points. In addition, the laser scanner can only collect 3D spatial data of objects, while texture and color data need to be processed by artificial mapping and texture mapping by digital camera shooting.

A structured light 3D scanner uses a raster projection unit to project a group of raster fringe with phase information onto the surface of the object. Using the principle of stereo camera measurement, it can quickly obtain high-density 3D data information on the surface of the object. It has the characteristics of fast scanning speed and high measurement accuracy. Also, this method still has data missing for surface highlights and cannot get the color information of the object.

Photographic 3D scanner (also called image modelling) is a more advanced technology products in recent years. The structured light and computer vision technology are fused to quickly get a series of images to calculate, the scanned object space position information is restored and the color of the object surface texture information is obtained at the same time. Because the reflectivity of the scanned object is less affected, relatively complete surface information can be

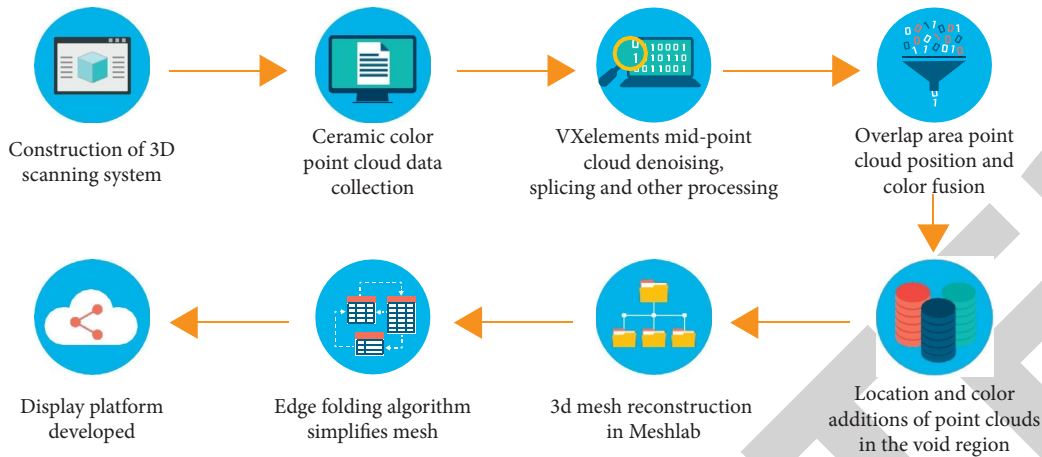


FIGURE 1: 3D reconstruction scheme.

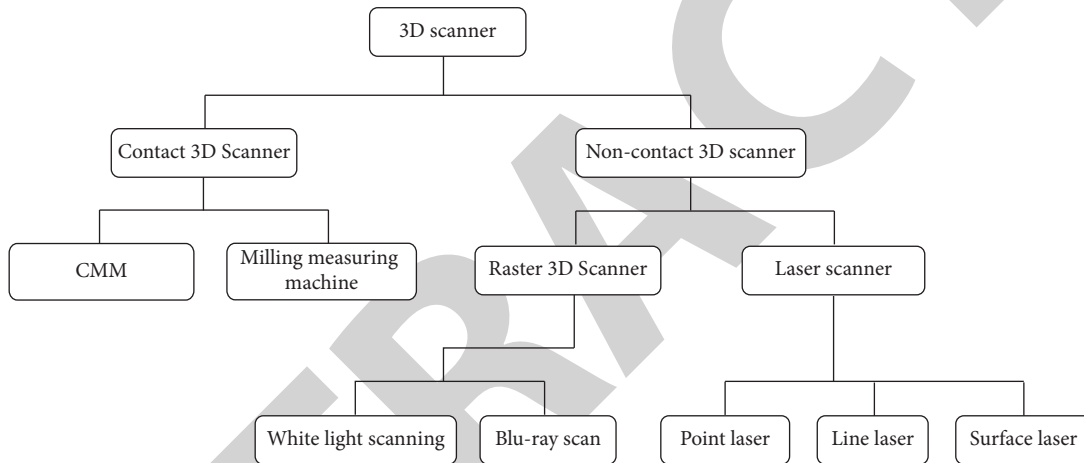


FIGURE 2: Classification of 3D scanners.

collected without spraying an imaging agent or other processing. As it is based on color digital image, 3D data with texture information can be obtained directly, which is very suitable for the digital collection of ceramic artworks.

Since it is impossible to scan the 3D information of each orientation of the same object at one time and most artworks have their own occlusion phenomenon, it is necessary to scan multiple times to obtain more comprehensive data in practical work. At the same time, 3D data acquired by scanning equipment still inevitably have problems such as noise points and data missing, which requires post-processing such as denoising, splicing, overlapping area fusion, and hole repair of the collected data. Finally, a complete 3D mesh model is obtained through meshing and the digital content is applied. Considering the above-given factors, the 3D reconstruction scheme of ceramic artworks is shown in Figure 1 [14].

3.2. 3D Data Acquisition and Processing

3.2.1. Acquisition of 3D Data of Ceramic Artworks. There are many kinds of 3D scanning equipment, which can be roughly

divided into two kinds: a contact scanner and a noncontact scanner. Contact scanner is mainly representative of the three coordinate measuring machine and milling measuring machine. Noncontact scanner has a raster 3D scanner and a laser scanner in two categories. Grating 3D scanner can also use white light scanning or blue-ray scanning two measurement methods. The laser scanner can be divided into point laser, line laser, and surface laser scanner according to the laser type [15] as shown in Figure 2.

The camera 3D scanner consists of two digital cameras, a color camera, a white light projector, and multiple LED white lights. It also uses two high-performance graphics workstations and is equipped with NVIDIA RTX graphics cards and special scan control software VX elements. During the scanning process, the ceramic artworks are placed on a disc-shaped rotating platform. In the process of acquisition, the 3D resolution of the collection point cloud is set as 0.2 mm and the accuracy of the 3D model obtained under this resolution is as high as 0.1 mm. In addition, the LED white light completely covers the scanning area and the acquisition work is carried out in a stable white light environment with no strong reflective objects around, which is conducive to accurately obtaining the color value of the

TABLE 1: Product parameters of the scanner.

Weight	950 g
Size	154 × 178 × 235 mm
Measuring rate	550,000 measurements per second
Scanning area	143 mm × 108 mm
Light source	White light (LED)
Resolution ratio	0.1 mm
Volume precision	0.3 mm/m
Locating method	Geometric shapes and/or colors and/or objects
Reference distance	380 mm
Depth of field	100 mm
Component size range (recommended)	0.05–0.5 m
Texture resolution	50–250 DPI
Texture color	24 bit
Software	VX elements

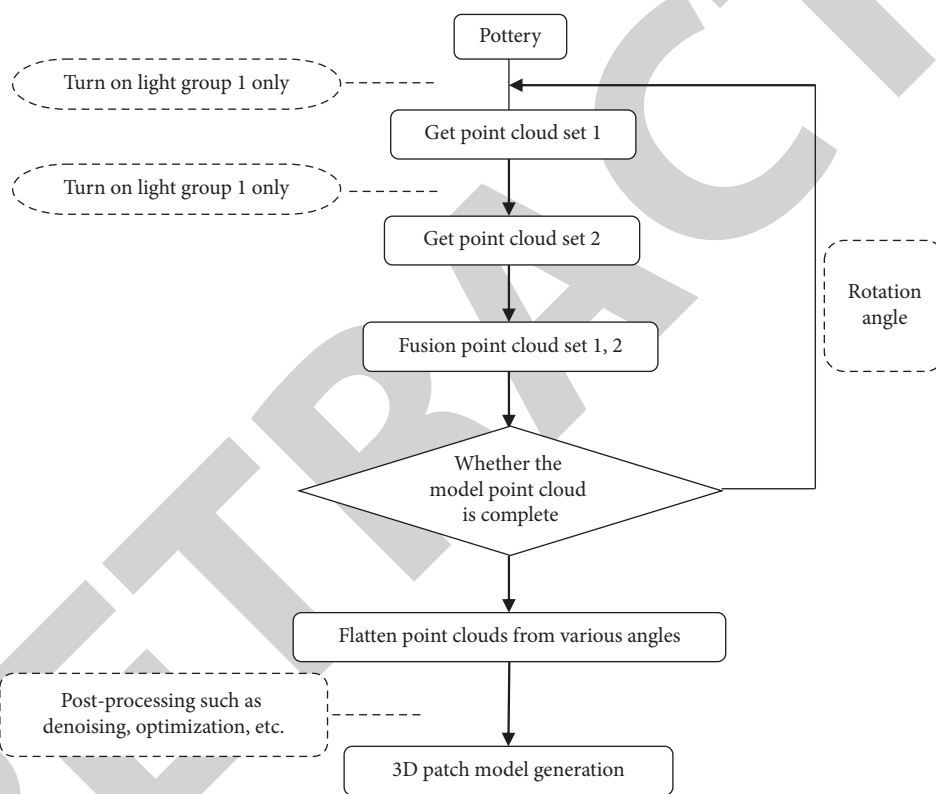


FIGURE 3: 3D model acquisition process.

surface of the ceramic artworks. The product parameters of the scanner are shown in Table 1.

3.2.2. Preprocessing of the Acquired Data. After the scanning and software calculation, 3D data still had some defects. It was mainly manifested as a large number of outliers. For the occluded parts, the data were lost inevitably so that holes appeared in some places. The 3D data obtained by fractional scanning needed to be spliced. Scanning control software VX elements was used to initially complete the removal of outliers, scanning data splicing, and hole repair. But the hole repair results were not ideal and overlapping data often existed in point cloud splicing, which required further fusion processing [16].

3.2.3. Point Cloud Acquisition Process. After determining the scanner model, the work of point cloud data acquisition of ceramic cultural relics began. The practice process was shown in Figure 3 [17]. First, with other environmental factors (the ceramic artwork placement position, scanner fixed position, etc.) unchanged, light group 1 and light group 2 were opened, respectively. The points from the same angle scanned under the two light groups were obtained successively and the point clouds of the two groups were aligned and fused. Then, it was judged whether the point cloud obtained in the above steps constituted a complete point gathering of the model. If not, the model was rotated at a certain angle (it varied according to the complexity of different ceramic models) and all the above-given steps were

repeated until the complete point gathering was obtained. The fused points obtained from various angles were gathered and spliced, denoised, optimized, and other postprocessing, and finally the 3D surface model of ceramic sculpture was obtained.

3.2.4. Alignment Fusion and Stitching Integration of Point Cloud Data. In order to align and fuse the two sets of point cloud data accurately, it was recommended to adopt the iterative nearest point algorithm, also known as the ICP algorithm. The ICP algorithm was simple and easy to implement iterative calculation. And, it could also achieve high matching accuracy, so it was an effective and fast algorithm. Figure 4 showed the flow chart of the ICP algorithm [18]. In practical application, the local extremum may fail to converge due to the improper initial point. The ICP algorithm was used mainly to calculate the matching relation between two sets of point gathering and the transformation parameter the rotation matrix R and the translation vector t of the two sets of point gathering through least square iteration. And, then the matching and alignment between two sets of point clouds were completed. The ceramic shapes were mainly characters, flowers, and birds, with prominent morphological characteristics, which was easy to define the corresponding marking points. In the experimental process, two groups of point cloud data were obtained under two groups of light sources with different directions according to the method proposed previously, namely, point gathering A and point gathering B . N pairs of identification points were determined in A and B as initial conditions. The least square method was used to calculate the minimum value of error function F . The formula was as follows. At this point, the rotation matrix R and the translation vector t were obtained [19].

$$F = \min \frac{1}{k} \sum_{i=1}^N B_i - (RA_i + t)^2. \quad (1)$$

4. Results and Analysis

4.1. Mesh Reconstruction of Color Point Cloud. The 3D ceramic data in the color point cloud form is in a discrete state, which requires surface mesh reconstruction. Namely, topological relations between points are established to obtain continuous surface characteristics so as to be applied to more development processes. The most commonly used mesh reconstruction methods include surface reconstruction algorithm based on the Poisson equation, Delaunay triangulation algorithm, and related optimization methods. Through the above-given work, ceramic color point cloud data can well maintain the uniform distribution law and retain normal information, providing an excellent data basis for Poisson mesh reconstruction [20].

Poisson mesh reconstruction can better mesh the original sharpness and angle characteristics of the ceramic and restore the shielding parts with a high degree of authenticity.

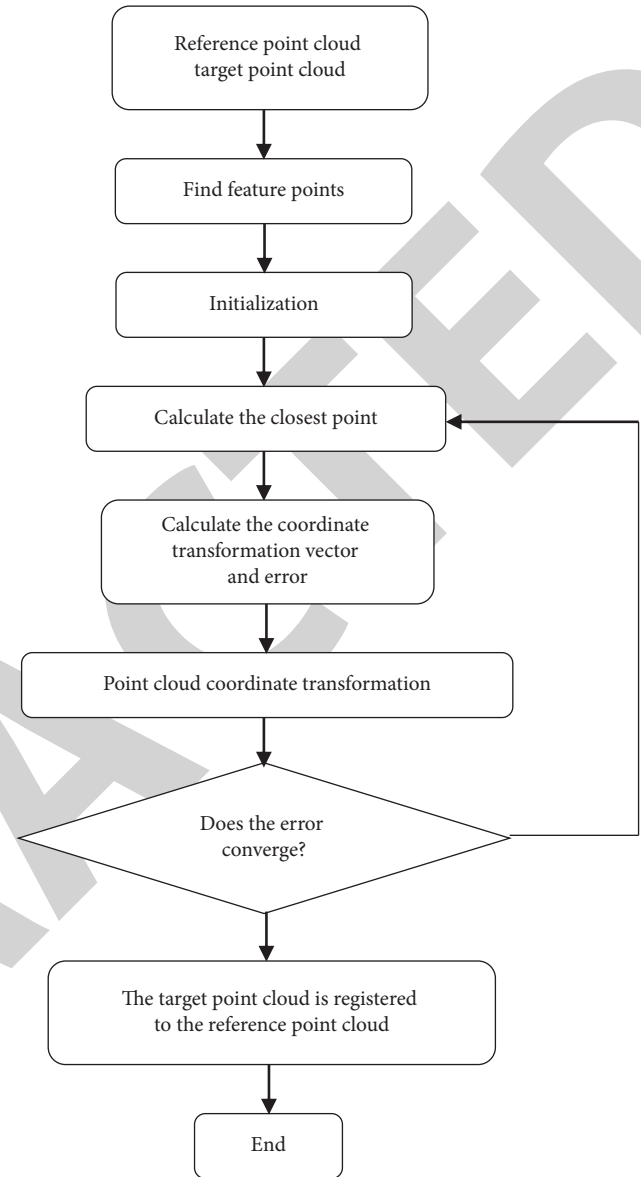


FIGURE 4: Flow chart of ICP algorithm.

4.2. Simplification of Color Mesh Model. The high-precision 3D mesh model obtained above records the detailed and complete information of ceramic works, which can not only provide professionals with the characteristics of ceramic sculpture techniques but also serve as the source data of 3D reproduction and physical restoration. However, due to its large amount of data and high resource occupation, it is not suitable for virtual display and Internet application directly, so simplifying the mesh complexity of the 3D model has become an essential link [21, 22].

The principle of model simplification is to reduce the number of model meshes as much as possible on the premise of ensuring information fidelity. Firstly, the vertex color information of the high-precision color mesh is mapped to the texture image by UV expansion, and the concave and convex information of the model surface is recorded into the normal map. Then, mesh simplification algorithms (such as

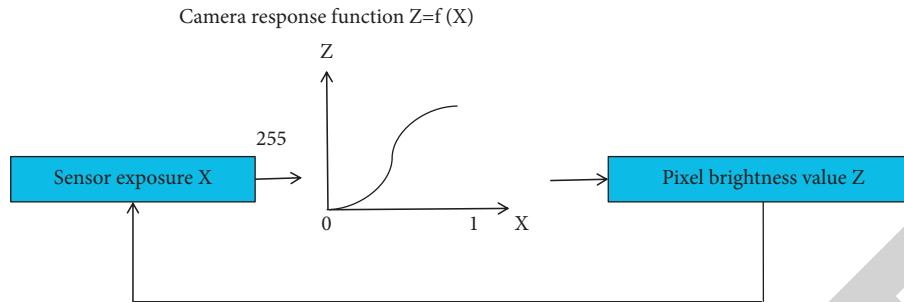


FIGURE 5: Camera response curve function.

Meshlab's edge folding simplification algorithm) are used to reduce the number of mesh faces and obtain the simplified low-precision mesh model. Finally, texture images and normal maps are baked onto low-precision mesh models to retain the visual effect of the original data to the maximum extent [23].

There are two software synthesis methods of HDR images, one is the pixel domain synthesis method and the other is the irradiated general image restoration and reconstruction method. The irradiance information content in natural scenes can be restored by solving the camera response function, synthesizing HDR images, and displaying HDR images [24]. The response function corresponding to the camera response curve can transform the radiation brightness of the real scene into the pixel value of camera imaging through the nonlinear system, as shown in Figure 5. The camera response function has the characteristics of propriety, smooth continuity, nonlinearity, and monotonicity. A sequence of Dharma images taken with multiple exposures are chosen and an exposure blend is selected, then Photomatix Pro allows you to choose +5 exposure blend methods on average in the 6 combined modes, each based on a different algorithm.

4.3. Development of Virtual Reality Application. The development of modern information technology and virtual reality opens up a new direction for the inheritance, activation, and popularization of cultural heritage. People do not have to spend the whole time on the museum and the exhibition hall and they can appreciate the artworks on a device in any place at any time.

Based on the previous research, a virtual display platform for ceramic artworks is developed including a computer terminal and mobile phone terminal. So the public can view ceramic artworks from a close distance and any angle and observe the rich glaze texture and morphological characteristics of ceramics from the details. In addition, the simplified mesh model of ceramics is also applied in the construction of a 3D ceramic display platform, and the tourism route with distinctive local cultural characteristics is jointly created with local museums so that people can know about ceramic artworks in advance [25].

5. Conclusion

With the development of science and technology and the progress of civilization, there will be more application

scenarios for the 3D digital reconstruction of cultural heritage, which plays a very positive role in promoting and inheriting traditional culture. Based on the characteristics of ceramic artworks, a 3D reconstruction method suitable for ceramic artworks with rich color information and complex shape was investigated and implemented. The method was efficient and convenient. And, the information was preserved completely. It was suitable for virtual reality application. At present, digital scanning and 3D reconstruction of 115 precious ceramic relics in the Ceramic Museum are completed. High-precision 3D ceramic mesh model is completed and related virtual reality applications are developed. With the continuous development of technology, this digital content will have more and more applications in the future. In general, the development of experimental software and hardware technology is still one of the reasons that restrict the wide application of this technology. The reconstruction and texture mapping of Shiwan ceramic relics by the existing 3D technology are difficult to be completely consistent with the original objects. However, problems such as the slow response speed of the virtual system and a lack of real-time operation still exist. But these problems can not prevent people from using digital technology to promote the process of digital protection of Shiwan ceramics.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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