Strategies for Digital Preservation and Transmission of Intangible Cultural Heritage Using CAD

Yan Wu[1] and Yongquan Liu[2]

[1]Academy of Fine Arts, Xinjiang Normal University, Urumqi, Xinjiang 830054, China, wuyan800424@163.com
[2]College of Education Science, Xinjiang Normal University, Urumqi, Xinjiang 830017, China, liuyongquan0629@163.com

Corresponding author: Yongquan Liu, liuyongquan0629@163.com

Abstract. With the acceleration of globalization and the advancement of modernization, intangible cultural heritage (ICH) faces unprecedented transmission challenges. This article aims to explore the digital protection and transmission strategies of ICH with the assistance of modern Computer-Aided Design (CAD) technology. To achieve this objective, the application of CAD technology in the digital protection and transmission of ICH is investigated, with a focus on key processes such as data acquisition, preprocessing, and refined modelling. The effectiveness of the proposed strategies is verified through practical case studies and experimental analysis. The research findings indicate that high-precision 3D scanners can rapidly and accurately capture the details of ICH objects, data preprocessing techniques significantly enhance the accuracy and usability of models, and refined modelling technology enables the digital reproduction of ICH objects, providing new avenues for their virtual display and interactive experiences. The digital protection and transmission strategies for ICH proposed in this article contribute to reducing the risk of damage to ICH from physical media and offer abundant materials and resources for subsequent exhibition, research, and transmission.

Keywords: Intangible Cultural Heritage; CAD Technology; Digital Protection; Inheritance Strategy
DOI: https://doi.org/10.14733/cadaps.2025.S7.243-255

1 INTRODUCTION

These ICHs, whether they are traditional skills taught by mouth or folk activities with local characteristics, bear rich historical memories and national feelings, which is an important embodiment of cultural diversity [1]. With the acceleration of globalization and the advancement of modernization, ICH is facing an unprecedented inheritance dilemma. Many traditional skills are gradually lost due to the lack of inheritors, and some unique folk activities are also drifting away in the wave of modernization. The concept of cultural heritage is constantly expanding, and the challenges faced in its protection work are also increasing. Due to the rapid economic transformation and uneven social development in China, there have been many unresolved and thought-provoking issues regarding digital protection in such a short period [2]. Although some achievements have been made in China's independently developed projects, due to technological backwardness, large-scale projects are mostly carried out in cooperation with foreign countries. With the changing survival status of cultural heritage and the rapid development of science and technology, many traditional protection methods are no longer suitable. This article suggests strengthening the construction of websites for museums and cultural heritage institutions [3]. We need new means of protection to replace and strengthen the digital construction of cultural heritage information resources and resource-sharing platforms, and use new media as a carrier to disseminate the digital achievements of cultural heritage protection., Digital protection technology is one of the fastest developing and most widely concerned technologies. However, due to various reasons, the protection of cultural heritage in our country started relatively late, and many places are not yet perfect, digital protection is even later, only more than ten years ago. Digital protection started relatively late and emerged only after the development of computer technology to a certain extent. From the time when computers became popular worldwide, the earliest was less than 30 years. However, a large number of technological means have been developed and considerable protection achievements have been made. Although China has a long history and culture, the splendid Chinese civilization has left us with a large amount of cultural heritage. During the construction process, it is important to pay attention to the integration of technology and cultural content, how to maintain the position of cultural subjects, cultural security, and strengthen standardized management. Modern CAD technology also promotes efficient management and global sharing of cultural heritage data. By integrating digital intangible cultural heritage into the education system, by offering relevant courses, and by organizing workshops and practical activities, students can learn and inherit intangible cultural heritage through practice. Modern CAD technology provides abundant teaching resources and tools for this, making the learning process more intuitive and vivid [4]. Through precise 3D modelling, every detail of these cultural heritages can be accurately recorded, providing a solid foundation for subsequent digital preservation and dissemination. For example, by using VR technology to reproduce traditional performance scenes or utilizing AR technology to overlay and display 3D models of handicrafts in the real world, the dissemination effect and public participation of cultural heritage have been greatly enhanced. By utilizing modern CAD technology, high-precision 3D modelling of intangible cultural heritage projects such as ancient architecture, traditional handicrafts, folk activities, etc. can be achieved. In the digital preservation of intangible cultural heritage, polygonization tools in CAD software can automatically or semi-automatically identify and extract key features of cultural heritage, such as textures, patterns, structural elements, etc [5]. This digital preservation method surpasses the limitations of traditional photography and two-dimensional drawings, allowing for a more comprehensive and three-dimensional preservation of cultural heritage information. As you mentioned, polygonization technology plays an important role in image processing. This is particularly important for the digital preservation of intangible cultural heritage, as it promotes information sharing and cooperation among different research institutions, museums, and cultural heritage conservation organizations [6]. Through unified data standards, a global digital resource library for intangible cultural heritage can be constructed, providing convenience for academic research, public education, and cultural exchange. These models can not only perfectly reproduce the form, structure, and details of the original object in the digital world, but also provide a scientific basis for subsequent restoration, replication, or exhibition through precise size measurement and material simulation. In the CAD environment, standardization of data formats can be achieved to ensure interoperability between different systems [7]. These features can then be used to generate binary masks for subsequent statistical analysis, comparative research, and digital restoration work.

As you mentioned, polygonization technology plays an important role in image processing. By utilizing modern CAD technology, high-precision 3D modelling of intangible cultural heritage projects such as ancient architecture, traditional handicrafts, folk activities, etc. can be achieved. In the digital preservation of intangible cultural heritage, polygonization tools are used in CAD software. It can automatically or semi-automatically identify and extract key features of cultural heritage, such as textures, patterns, structural elements, etc. This digital preservation method surpasses the limitations of traditional photography and two-dimensional drawings, allowing for a more comprehensive and three-dimensional preservation of cultural heritage information [8]. These features can then be used to generate binary masks for subsequent statistical analysis, comparative research, and digital restoration work. This is particularly important for the digital preservation of intangible cultural heritage, as it promotes information sharing and cooperation among different research institutions, museums, and cultural heritage conservation organizations. These models can not only perfectly reproduce the form, structure, and details of the original object in the digital world, but also provide a scientific basis for subsequent restoration, replication, or exhibition through precise size measurement and material simulation. Data standardization and interoperability [9]. In the CAD environment, standardization of data formats can be achieved to ensure interoperability between different systems.

(1) Based on modern CAD technology, especially 3D scanning and modelling technology, this article provides a new research perspective for the protection and inheritance of ICH.

(2) This study discusses the application of a refined processing algorithm based on 3D scanning and modelling in the protection and inheritance of ICH. This article not only introduces the basic principles of these technologies but also analyzes in detail their specific application strategies in ICH data acquisition, preprocessing, fine modelling and other links.

(3) When discussing the digital protection and inheritance of ICH, this article particularly emphasizes the importance of sustainable development and puts forward that while promoting digitalization, we should also pay attention to the inheritance and development of ICH in real life.

Firstly, this article expounds on the importance of ICH and its inheritance dilemma and introduces the application potential of modern CAD technology, especially 3D scanning and modeling technology, in ICH protection. Then, the characteristics and value of ICH are introduced in detail, and the specific application strategies of refined processing algorithm based on 3D scanning and modelling in ICH data acquisition, preprocessing and refined modelling are discussed. Finally, the feasibility analysis is carried out with specific cases and experiments to show the practical path and practicability of digital protection.

2 OVERVIEW OF INTANGIBLE CULTURAL HERITAGE (ICH)

Using modern CAD technology, Liu et al. [10] carried out high-precision 3D scanning of Terra Cotta Warriors fragments to obtain their complete 3D shape data. Based on the MLP calculation results, the system can intelligently select appropriate splicing strategies and methods to match and splice Terra Cotta Warriors fragments accurately. Cultural heritage is the concrete manifestation of past information today, whether tangible or intangible, on the brink of disappearance. In the past, we used to cherish some lost civilizations, but we were powerless against those that were disappearing. For intangible cultural heritage, digitization can also provide great assistance, not only in disseminating its cultural content but also in having advantages. Even if the intangible cultural heritage that has lost its inheritance cannot be found, it can still be preserved for future generations through digital technology. What traditional protection methods cannot achieve, the development of digital technology has provided us with some better methods. And some cultural heritage that has already disappeared can be revitalized through this, such as the digital reconstruction of the Yuanmingyuan. We can feel its magnificent scenery through the digital virtuality of this former Garden of Ten Thousand Gardens. It is to preserve the treasures of Dunhuang as much as possible in another time and space and, to a large extent, to reduce the damage caused to murals and sculptures by tourists when visiting physical caves. Some disappearing cultures can continue their lives through digital technology, such as the ongoing "Digital Dunhuang" project. Liu et al. [11] consciously utilized digital means to preserve a portion, although many inheritors were out of touch with the times. For example, there are a large number of intangible cultural heritages in China that have lost their inheritance before they can be protected. There are some simple ways to achieve this; even a few photos taken with a mobile phone in a simple video can serve as the basis for the existence of this culture in the past.

Based on conducting research on BIM and digital protection and reuse of industrial heritage, this paper reveals the exploratory significance of BIM technology in the digital protection and reuse of industrial heritage. Especially the innovation of the industrial heritage digital information database and industrial heritage digital information exchange platform that combine BIM, GIS and other hybrid digital technologies. This mainly introduces the source, purpose, significance, research methods, and article framework of the research topic. At present, the digital protection and reuse of industrial heritage combined with BIM in China is still in its infancy, lacking a systematic theoretical basis and related technological research. Pierdicca et al. [12] proposed the necessity and feasibility of combining BIM technology to implement digital protection and reuse of industrial heritage. The definition and characteristics of digitalization of industrial heritage, as well as an overview of related BIM research, were proposed separately. Explored the existing problems in the protection and reuse of industrial heritage under the background of rapid urbanization, and provided the motivation for this research topic. The comprehensive demonstration of the digital protection and reuse strategy of industrial heritage using BIM technology mainly involves relevant principles, research on BIM security systems, research on BIM implementation framework, and research on industrial heritage digital information database combined with BIM. It focuses on demonstrating the profound changes brought by the industrial heritage information database combined with BIM and GIS technology to the field of industrial heritage protection and reuse. The development of 3D digital technology represented by BIM technology has injected vitality into the field of industrial heritage protection and reuse, breaking through the previous situation of a single element and providing full lifecycle protection for industrial heritage. In addition, social media can also serve as a channel for collecting public feedback and suggestions, providing new ideas and directions for the digital protection and dissemination of cultural heritage. Through interactive learning experiences, students can gain a more intuitive understanding of the historical background, production techniques, and cultural connotations of cultural heritage. By initiating themed discussions, online Q&A, creative challenges, and other activities, the public's interest and enthusiasm for cultural heritage can be stimulated, promoting the inheritance and development of cultural heritage. In summary, the digital preservation and dissemination strategies of intangible cultural heritage under modern CAD technology not only improve the digitalization level and protection efficiency of cultural heritage but also broaden its dissemination scope and influence. In the future, with the continuous advancement of technology and the expansion of applications, we have reason to believe that the digital protection and dissemination of cultural heritage will usher in broader development prospects.

As mentioned in the article, intelligent recognition technologies such as deep learning have shown great potential in the genetic recognition of historical buildings. Radosavljevi and Ljubisavljevi [13] used CAD technology to construct digital models that enable historical buildings to be permanently preserved in digital form. The application of these technologies not only makes the identification of the "genes" of historical buildings more accurate and efficient but also provides strong technical support for the digital preservation of historical buildings. Combining advanced algorithms such as the improved U-Net model with channel attention mechanisms can significantly improve recognition accuracy and efficiency, overcoming problems such as qualitative subjectivity and quantization difficulties in traditional methods. These digital models can not only be deeply studied and analyzed in professional institutions but also be widely disseminated through the Internet and other channels. Viewers can experience the charm of historical buildings through advanced technologies such as virtual reality and augmented reality, thereby achieving cross-regional and cross-era dissemination of cultural heritage. In addition, digital protection also promotes remote monitoring and maintenance of historical buildings, timely detection and resolution of problems, and ensuring effective protection of their historical features. Reversibility is manifested in the process of digitizing industrial heritage. As is well known, traditional survey methods mainly include note taking, hand drawing, and ruler measurement, which are easily influenced by subjective factors of surveyors and often result in biased survey results. Reversibility is manifested in the process of modifying information data. When we use digital technology to construct information models, data with errors can be corrected using digital products such as computers, and this correction will be reflected in the final virtual display through digital products. Simply put, we can extract various relevant information about industrial heritage and convert it into numbers, encode them into computers, or display these numbers and codes in visual images, pictures, and other forms through digital products such as computers. For example, in the process of industrial heritage survey, digital products and laser measuring instruments can be used to survey the information of industrial heritage. When it is necessary to modify the data, a computer can be used to modify a certain data element, and this change will be presented in the final model presentation. Compared to the traditional process of modifying solutions, digital technology can modify problem data more targetedly and save a lot of modification time. It can be seen that the reversibility of digital technology provides technical support for the accurate and complete recording, storage, transfer, and backup of industrial heritage information. The obtained photos, images, and other materials are stored in encoded form in digital products, which can then be transformed into virtual images through digital products to present industrial heritage information to people in a realistic way. Therefore, such reversibility provides technical support for us to repeatedly modify creative schemes and improve the accuracy of information models. The future development direction is to further refine the preprocessing process, develop more intelligent tools, reduce manual intervention, and improve automation levels.

Intangible cultural heritage refers to traditional culture, customs, activities, and skills, as well as related tools, devices, handicrafts, and cultural sites. These intangible cultural heritages reflect people's rich creativity, showcase China's history, and are an important component of people's identity recognition. They have become treasures of human civilization due to their vividness, inheritability, and cultural characteristics. Vividness is one of the core characteristics of intangible cultural heritage. Unlike tangible cultural heritage, intangible cultural heritage is not static and unchanging, but living and constantly changing. They exist in people's daily lives and develop and evolve with the changes of the times. Shao and Sun [14] analyzed that intangible cultural heritage has strong vitality and adaptability, and can survive and develop in different social environments and historical conditions. Inheritance is another important characteristic of intangible cultural heritage. Intangible cultural heritage is usually passed down from generation to generation through oral traditions. This inheritance method conveys skills and knowledge, as well as cultural values and national spirit. It is this inheritance that allows intangible cultural heritage to continue for thousands of years, becoming an important link between the past and the future. Cultural identity is the profound value of intangible cultural heritage. Intangible cultural heritage is an important symbol of people's identity, carrying rich historical memories and national emotions, and is an important manifestation of cultural diversity. Trček [15] believes that through intangible cultural heritage, people can find their cultural roots and enhance their sense of identity with national culture. At the same time, intangible cultural heritage is also an important bridge for cultural exchange between different ethnic groups, which helps promote cultural diversity. However, with the acceleration of globalization and the advancement of modernization, intangible cultural heritage is facing unprecedented difficulties in inheritance. Due to the lack of inheritors, many traditional skills have gradually been lost, and some unique folk activities have also disappeared in the wave of modernization. Therefore, protecting and inheriting intangible cultural heritage has become an urgent task for people.

3 DIGITAL PROTECTION AND INHERITANCE STRATEGY OF ICH

3.1 Data Acquisition Strategy

Data acquisition is the first step of ICH digital protection. The 3D scanning technology in CAD technology can capture ICH objects or scenes quickly and accurately. In the stage of data acquisition, it is necessary to choose the appropriate scanning equipment to ensure that every detail of the ICH object can be captured. At the same time, it is also very important to set a reasonable scanning environment to avoid the adverse effects of light, shadow and other factors on the scanning results.

In practice, the scanning equipment needs to be calibrated to ensure the measurement accuracy. Then, according to the characteristics of the ICH project and scanning environment, set appropriate scanning parameters; Then, the ICH project is fully captured by scanning equipment. Finally, the original data collected are preliminarily processed, such as data splicing, cutting and format conversion. See Figure 1 for the process of ICH3D scanning and model construction. Fine modeling techniques are not only key to improving model fidelity and integrity, but also an important foundation for achieving ICH virtual display and interactive experience. The digital protection work of ICH requires interdisciplinary and multidisciplinary collaboration. Through the case and experimental analysis in this section, we have witnessed the significant effectiveness of the digital protection and inheritance strategy for intangible cultural heritage in practical applications. Meanwhile, cross-disciplinary research with fields such as history, ethnology, sociology, etc. will also help to deeply explore the cultural connotations and social values of ICH. These practices not only provide new avenues for the sustainable development of intangible cultural resources but also contribute significantly to the protection and inheritance of global cultural diversity. For example, the deep integration with fields such as computer graphics, human-computer interaction, and animation design will bring more possibilities for ICH's virtual display and interactive experience. In the future, we can look forward to the emergence of more innovative modelling technologies, such as automatic modelling based on deep learning and modelling supported by mixed reality (MR). These technologies will further enrich modelling methods and improve modelling efficiency and quality.

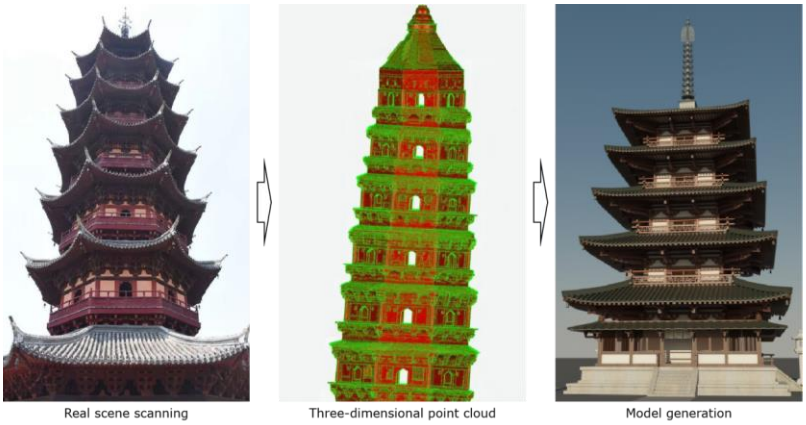

Figure 1: 3D scanning and model construction.

For the intangible forms such as performing arts and oral traditions in ICH, although 3D scanning cannot be directly performed, digital recording can be performed using high-definition video recording and audio recording, providing materials for subsequent modelling and display. In addition, for some ICH objects that can't be directly contacted or easily damaged, non-contact scanning technology, such as laser scanning and grating scanning, can be adopted to reduce the damage to the original objects.

3.2 Data Preprocessing Technology

Data preprocessing is a bridge between data acquisition and fine modelling, and its purpose is to improve the accuracy and availability of data. In CAD technology, data preprocessing mainly includes data cleaning, denoising, registration and splicing.

Firstly, redundant information and noise generated during scanning are removed by data cleaning to improve the purity of data. Secondly, denoising technology is used to smooth the data surface further and reduce the errors caused by the precision limitation of scanning equipment or environmental factors. Next, the data of multiple scanning perspectives are aligned by data registration technology to ensure the coherence and consistency of the overall model. Finally, the registered data segments are merged into a complete 3D model by stitching technology.

3.3 Refined Modeling Method

Fine modelling is the core link of ICH digital protection, and it is also the place where CAD technology plays its greatest role. Through fine modelling, the ICH object can be reproduced in digital form, and its virtual display and interactive experience can be realized.

When the camera is positioned at two distinct points, let C_1, C_2 denote the corresponding local coordinate system. The transformation parameters with the world coordinate system are R_1, T_1, R_2, T_2. Consider any point P in the world coordinate system; its coordinates in this system are X_w x_w, y_w, z_w , and in the C_1, C_2 coordinate system, they are X_{c1} x_{c1}, y_{c1}, z_{c1} ,X_{c2} x_{c2}, y_{c2}, z_{c2} . The relationship between these is as follows:

$$\begin{cases} X_{c1} = R_1 X_w + t_1 \\ X_{c2} = R_2 X_w + t_2 \end{cases} \tag{1}$$

The transformation relationship between C_1, C_2 's two coordinate systems can be derived by eliminating X_w from the aforementioned formula.

$$X_{c1} = R_1 R_2^{-1} X_{c2} + t_1 - R_1 R_2^{-1} t_2 = R X_{c2} + t \tag{2}$$

To ascertain the coordinates of any point in the C_1 coordinate system relative to the world coordinate system; one can establish the latter as the benchmark, leveraging its coordinate origin (0,0,0) and aligning the three coordinate axes as reference directions. The methodology behind vanishing point calibration is illustrated in Figure 2.

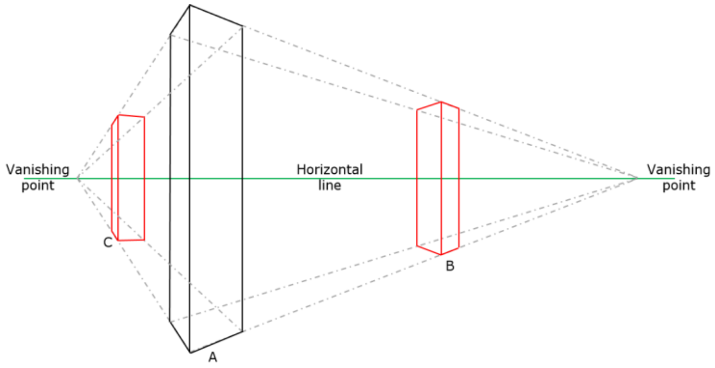

Figure 2: Principle of vanishing point calibration.

The eleven degrees of freedom in the projection matrix P can be decomposed into a rotation matrix R, a translation matrix T, and a 3×3 camera calibration matrix K.

$$P = M\left[I \middle| M^{-1} P_4\right] = KR\left[I \middle| -C\right] = K\left[R, T\right] \tag{3}$$

During modelling, the initial step involves constructing a geometric model based on preprocessed data. This entails utilizing CAD software tools to fit, repair, and optimize scanned data, ultimately forming a comprehensive 3D geometry. Additionally, texture mapping is applied to the model, enhancing its vividness by incorporating details such as surface material and colour from ICH objects.

To mitigate noise, a smoothing function can be applied to convolve with the image function. Specifically, the Gaussian smoothing function is utilized:

$$G(x,y,\sigma)=\frac{1}{2\pi\sigma^2}\exp\left(\frac{x^2+y^2}{2\sigma^2}\right) \tag{4}$$

A smaller adjustable parameter σ results in higher spatial positioning accuracy but poorer suppression of high-frequency noise. To obtain an improved photo group $V(p)$, patch filtering is applied using the following formula:

$$\left|V^*(p')\right|(1-g^*(p))<\sum_{p\in U(p)}(1-g^*(p)) \tag{5}$$

Here, $U(p)$ denotes the collection of patches that fail to meet the necessary visible information criteria.

When M is defined as a solid model, the spatial indicator function employed in surface reconstruction is given by:

$$\Phi(p)=\begin{cases}1, & p\in M\\ 0, & p\notin M\end{cases} \tag{6}$$

Directly applying this method can lead to background saturation and blending of the subject with the background. To address this, this article introduces a threshold to ensure reasonable limitations. Thus, histogram counting involves statistical analysis with thresholds assigned to grey pixels:

$$p(\alpha_i)=\begin{cases}\dfrac{p}{h} & h_i>p\\ \dfrac{h_i}{h} & h_i<p\end{cases} \tag{7}$$

The formula $p(\alpha_i)$ denotes the occurrence probability of the i gray value, h represents the total pixel count, and α_i signifies the background grayscale.

For a $M\times N$ gray image with a maximum gray level of L, where the number of pixels with a specific gray level i is n_i, and the corresponding probability is P_i, the image gray entropy H is calculated as follows:

$$H=-\sum^{L}P_i\times\log_2 P_i \tag{8}$$

By selecting the threshold $t\in G_L$ and a pair of binary grey levels $B=\left[a,b\right]$, where $a,b\in G_L$, the thresholding of image $f(i,j)$ can be formulated as follows:

$$f(i,j)=\begin{cases}S_a, & f(i,j)>t\\ S_b, & f(i,j)\le t\end{cases} \tag{9}$$

The region where S_a meets the condition $f(i,j)>t$ is referred to as the target area, while the area where S_b satisfies $f(i,j)\le t$ is termed the background area. Prior to extracting edge features from an ICH image, it is essential to smooth the root image to eliminate noise interference. This involves removing areas with rapid grey changes without altering the image's overall characteristics. The Gaussian filter is effective in smoothing noise and bridging gaps between image objects. Its close proximity to its first derivative makes it a frequent choice for removing noise in orthometric distributions. The corresponding calculation formula for the Gaussian filter is:

$$g(i,j)=\frac{1}{2\pi\sigma^2}\exp\left[-\frac{x^2+y^2}{2\sigma^2}\right] \tag{10}$$

The provided formula σ represents the scale of the Gaussian function. The smoothing effect of the Gaussian filter is strongly influenced by the parameter σ, making the determination of the σ value crucial.

The bilateral filtering algorithm, defined as follows, is applied to the denoising process of 3D point cloud data:

$$g := g + am \tag{11}$$

In this context, g denotes the data point, a represents the bilateral filtering weight factor, and m signifies the normal direction of the data point g.

The dynamic elements and physical characteristics in ICH, such as the action flow of performing arts and the craftsmanship of handicrafts, can be reproduced by animation simulation and physical simulation technology. In the process of fine modelling, it is necessary to pay attention to the accuracy and authenticity of the model to ensure that the digital model can truly reflect the characteristics and connotations of ICH objects. In addition, the compatibility and expansibility of the model need to be considered, so that it can be seamlessly connected with other digital platforms and technologies in the future exhibition and dissemination process.

3.4 Protection and Inheritance of ICH Combined with CAD Technology

Establishment of ICH digital archive: Establish a 3D digital model library of ICH with CAD technology, and save and manage various ICH objects in digital form. This will help to reduce the risk of physical media damage to ICH and provide rich materials and resources for subsequent display, research and inheritance.

Promote the virtual display and interactive experience of ICH: Through the refined model constructed by CAD technology, combined with advanced technologies such as virtual reality (VR) and augmented reality (AR), the virtual display and interactive experience of ICH can be realized. The audience can feel the charm of ICH in the virtual environment and increase their understanding and recognition of ICH.

Promote the inheritance and education of ICH: integrate CAD technology into the inheritance and education of ICH, and increase the interest and participation of the younger generation in ICH through digital means. For example, we can develop ICH teaching software or online courses based on CAD technology, so that students can master ICH knowledge and skills in interactive learning.

Strengthen the dissemination and promotion of ICH: The digital model of ICH constructed by CAD technology will be widely disseminated through Internet platforms and social media. This can expand the influence of ICH and attract more social forces and capital to pay attention to the protection and inheritance of ICH.

4 CASE AND EXPERIMENTAL ANALYSIS

In order to verify the effectiveness of the digital protection and inheritance strategy of ICH, this section will analyze it with specific cases and experiments. Through the actual data collection, preprocessing, fine modelling and other links, the practical application effect of CAD technology in ICH protection and inheritance is demonstrated.

4.1 Data Acquisition and Processing

In the data acquisition stage, a high-precision 3D scanner was used to scan the traditional ceramic works comprehensively. Through reasonable scanning environment setting and scanning parameter adjustment, high-quality point cloud data are obtained. Next, the point cloud data is preprocessed.

Through data cleaning, denoising, registration and stitching, a complete 3D geometric model is obtained. Figure 3 shows the effect of the 3D geometric model after preprocessing.

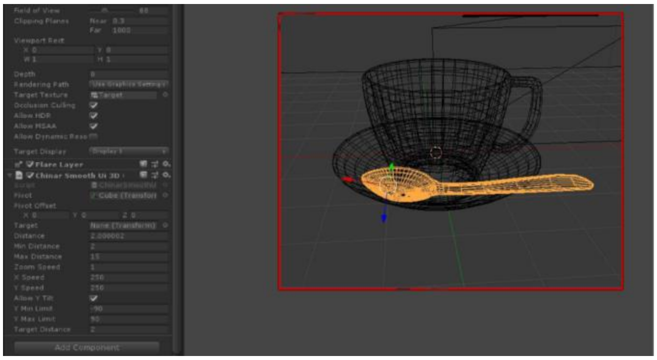

Figure 3: 3D geometric model after preprocessing.

4.2 Fine Modeling and Effect Display

In the fine modelling stage, the pre-processed data are fitted, repaired and optimized by using the modelling tools of CAD software, and a complete 3D geometric shape is formed. At the same time, texture mapping is added to the model to make it more realistic and vivid. Figure 4 shows the digital model of traditional ceramic art after fine modelling.

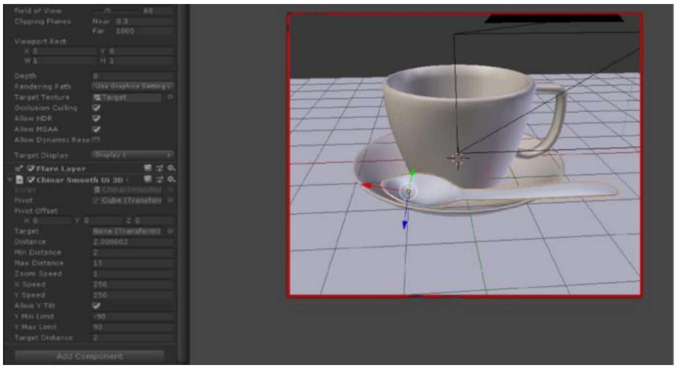

Figure 4: Digital model after refined modeling.

In order to further show the effect of digital protection and inheritance, the digital model after fine modelling is compared with the original ceramic works. By comparison, it can be found that the digital model maintains a high degree of consistency with the original work in detail and overall form.

4.3 Experimental Data Analysis

In order to show the effect of digital protection and inheritance strategy more intuitively, the experimental data are deeply analyzed. The time consumption and model quality of data acquisition, preprocessing and fine modelling are recorded respectively, and the corresponding line charts are drawn.

Figure 5 shows the relationship between the time consumption of data acquisition and the model quality. With the increase in scanning time, the quality of the model has been improved accordingly.

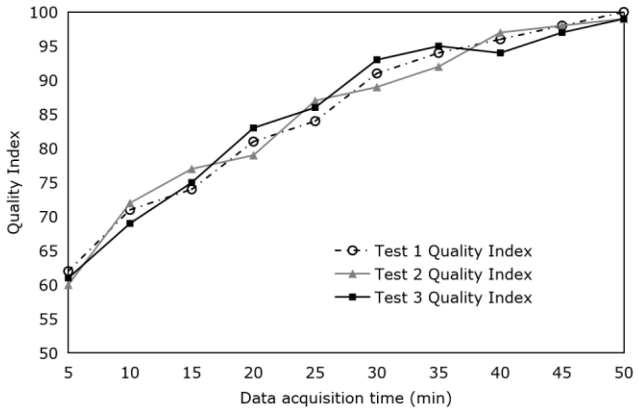

Figure 5: Relationship between data acquisition time consumption and model quality.

Figure 6 shows the influence of pretreatment on the model quality. By comparing the model quality indexes before and after pretreatment, it can be found that the pretreatment step has a significant effect on improving the model quality.

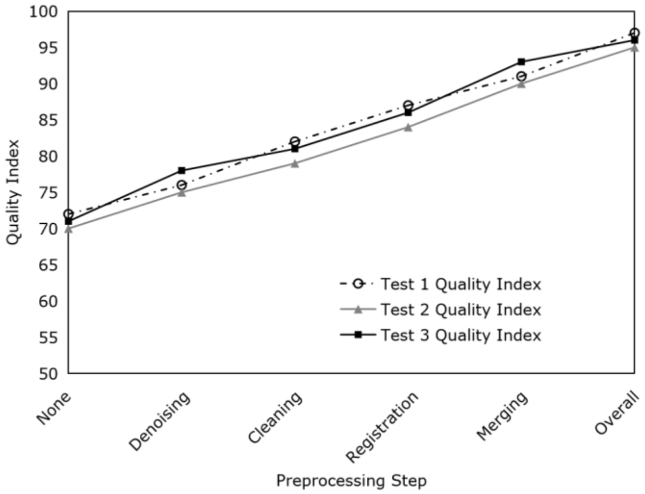

Figure 6: Influence of pretreatment on model quality.

Figure 7 shows the influence of refined modelling on the details and overall shape of the model. By comparing the model effects before and after refined modelling, we can find that refined modelling can significantly improve the fidelity and integrity of the model. This proves the key role of fine modelling technology in ICH's digital protection.

4.4 Summary of Cases and Experiments

The digital protection process of cultural heritage heavily relies on software and hardware facilities, requiring the use of numerous devices and a large number of computer software and hardware to assist in the collection, statistics, processing, storage, and display of heritage information. This is understandable, but there is no guidance on how to choose the most suitable equipment within the budget range, as there may be compatibility issues or other problems with the data generated during processing.

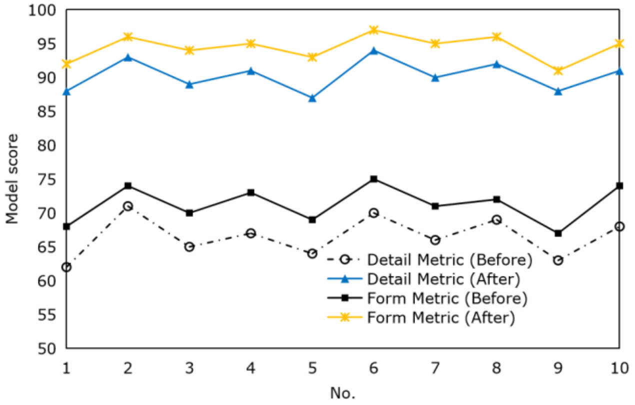

Figure 7: Influence of refined modelling link.

The country has not established a unified data processing standard or specification. It is difficult for people to obtain accurate information on the progress of protecting digital cultural heritage. Although digital cultural heritage is very popular now, with many places and units participating, and many projects proposed early on, the results have not been seen for a long time, or even if there are results, they are not known to people. We often see news about the digital protection of a certain cultural heritage in a certain place, but when we want to delve deeper, we often cannot get further information. And the current situation is that we can only search for information if we know the relevant projects, which is only helpful for industry insiders. If a person is not familiar with digital cultural heritage and only wants to know about the progress, it is quite difficult for them. There are many choices in this process, such as when choosing equipment, it is often necessary to start with cost.

5 CONCLUSIONS

This study delves into the application strategy of CAD technology in the digital protection and inheritance of ICH and validates it through specific cases and experiments. The findings indicate that modern CAD technology, particularly 3D scanning and modelling, plays a crucial role in this domain. Utilizing a high-precision 3D scanner, every detail of the ICH object can be swiftly and accurately captured, laying a solid data foundation for further digital protection and inheritance. Moreover, data preprocessing techniques enhance data accuracy and availability, ensuring precise and authentic digital models. Fine modelling technology reproduces ICH objects in digital form, enabling the virtual display and interactive experiences, and offering a novel approach to ICH dissemination and promotion. Through case and experimental analysis, the efficacy of the proposed digital protection and inheritance strategy for ICH is confirmed. Practical applications demonstrate that this strategy mitigates the risk of physical media damage to ICH and provides valuable resources for subsequent display, research, and inheritance.

6 ACKNOWLEDGEMENT

The Social Science Foundation of Xinjiang Uygur Autonomous Region "Empirical Research on the Creative Transformation of Symbolic Symbols in Xinjiang Folk Art" (2024 BYS129) stage achievement.

Yan Wu, https://orcid.org/0009-0000-8004-9709
Yongquan Liu, https://orcid.org/0009-0002-6124-3965

REFERENCES

[1] Amura, A.; Aldini, A.; Pagnotta, S.; Salerno, E.; Tonazzini, A.; Triolo, P.: Analysis of diagnostic images of artworks and feature extraction: design of a methodology, Journal of Imaging, 7(3), 2021, 53. https://doi.org/10.3390/jimaging7030053
[2] Bardhan, S.; Paul, S.: The cultural landscape of the Bhagirathi-Hooghly riverfront in Kolkata, India: studies on its built and natural heritage, Journal of Cultural Legacy Management and Sustainable Development, 13(2), 2023, 219-237. https://doi.org/10.1108/JCHMSD-08-2020-0119
[3] Bozorgi, K.; Lischer, K.-Z.: Using 3D/VR for research and cultural legacy preservation: project update on the virtual Ganjali Khan project, Preservation, Digital Technology And Culture, 49(2), 2020, 45-57. https://doi.org/10.1515/pdtc-2020-0017
[4] Cao, Y.; Scaioni, M.: 3DLEB-Net: Label-efficient deep learning-based semantic segmentation of building point clouds at LoD3 level, Applied Sciences, 11(19), 2021, 8996. https://doi.org/10.3390/app11198996
[5] Comes, R.; Neamțu, C.-G.-D.; Grec, C.; Buna, Z.-L.; Găzdac, C.; Mateescu, S.-L.: Digital Reconstruction of Fragmented Cultural Heritage Assets: The Case Study of the Dacian Embossed Disk from Piatra Roșie, Applied Sciences, 12(16), 2022, 8131. https://doi.org/10.3390/app12168131
[6] Croce, V.; Caroti, G.; Luca, L.; Jacquot, K.; Piemonte, A.; Véron, P.: From the semantic point cloud to heritage-building information modeling: A semiautomatic approach exploiting machine learning, Remote Sensing, 13(3), 2021, 461. https://doi.org/10.3390/rs13030461
[7] Demenchuk, E.; Camelia, I.-D.; Wendt, J.-A.: Spectroscopy study of heritage objects for the digitization of cultural heritage, Environmental Engineering and Management Journal, 19(6), 2020, 1057-1066. https://doi.org/10.30638/EEMJ.2020.100
[8] Kotsiubivska, K.; Baranskyi, S.: 3D simulation in the restoration of historical and cultural values, Digital Platform Information Technologies in Sociocultural Sphere, 3(1), 2020, 59-68. https://doi.org/10.31866/2617-796x.3.1.2020.206109
[9] Li, F.; Gao, Y.; Candeias, A.-J.-E.-G.; Wu, Y.: Virtual restoration system for 3D digital cultural relics based on a fuzzy logic algorithm, Systems, 11(7), 2023, 374. https://doi.org/10.3390/systems11070374
[10] Liu, K.; Gao, Y.; Zhang, J.; Zhu, C.: Study on digital protection and innovative design of Qin opera costumes, Heritage Science, 10(1), 2022, 127. https://doi.org/10.1186/s40494-022-00762-x
[11] Liu, K.; Zhou, S.; Zhu, C.; Lü, Z.: Virtual simulation of Yue Opera costumes and fashion design based on Yue Opera elements, Fashion and Textiles, 9(1), 2022, 31. https://doi.org/10.1186/s40691-022-00300-0
[12] Pierdicca, R.; Paolanti, M.; Matrone, F.; Martini, M.; Morbidoni, C.; Malinverni, E.-S.; Lingua, A.-M.: Point cloud semantic segmentation using a deep learning framework for cultural heritage, Remote Sensing, 12(6), 2020, 1005. https://doi.org/10.3390/rs12061005
[13] Radosavljevi, Z.; Ljubisavljevi, T.: Digitization of cultural legacy as a potential for increasing museum attendance in Central Serbia, Bizinfo Blace, 10(1), 2019, 53-67. https://doi.org/10.5937/bizinfo1901053R
[14] Shao, L.; Sun, J.: Identification of historic building "genes" based on deep learning: a case study on Chinese baroque architecture in Harbin, China, Heritage Science, 11(1), 2023, 241. https://doi.org/10.1186/s40494-023-01091-3
[15] Trček, D.: Cultural heritage preservation by using blockchain technologies, Heritage Science, 10(1), 2022, 6. https://doi.org/10.1186/s40494-021-00643-9