

# Applied Mathematics and Nonlinear Sciences

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## Design and realization of the digital protection platform of traditional intangible cultural heritage based on virtual reality technology

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### Abstract

Using new design concepts and design methods to effectively strengthen the digital protection of traditional non-heritage culture is an important measure to promote the development of conventional non-heritage culture. In this paper, the digital protection needs of traditional non-heritage culture are sorted out, including the purpose of digital protection of non-heritage, the design level, and the feasibility of the application of virtual reality technology in the digital protection of non-heritage culture. A platform for the digital protection of non-heritage culture is constructed with the model of PHP technology + MySQL database + Apache server combined with virtual reality technology, and the immersion experience and display dissemination model is designed in this platform. In order to obtain accurate digital images of traditional non-heritage culture, this paper utilizes 3D laser point cloud acquisition technology to reconstruct non-heritage culture in 3D. It combines the ICP algorithm to enhance the point cloud alignment accuracy of digital images of non-heritage culture. Evaluation of the effectiveness of the traditional non-heritage culture digital protection platform proposed in this paper was done through performance tests and application practice. The results show that the number of concurrent users of the platform in this paper can reach the maximum throughput of about 94,300 per second in 2000, the point cloud alignment accuracy of the ICP algorithm has an error of only 0.304mm, and the SUS usability evaluation of the platform scores 80.4 points. The construction of a digital protection platform for non-heritage culture using virtual reality technology can provide users with immersive experience scenes.

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**Keywords:** Virtual reality technology; Digitization; 3D reconstruction; ICP algorithm; Point cloud alignment; Traditional non-heritage.

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## 1 Introduction

Cultural revitalization promotes industrial development, and intangible cultural heritage is an important part of China's outstanding traditional culture [1]. Protecting, inheriting, and promoting non-heritage in ethnic areas is of great significance for firming cultural confidence and building a strong socialist culture [2]. The development of digital technology provides a new opportunity for the protection of non-legacy. The inheritance and revitalization of non-legacy in ethnic areas driven by advanced technology has become an important innovative development strategy [3]. The digitization of national regional non-legacy is a key link in the revitalization and dissemination of non-legacy in the new era, relying on digital technology, reshaping the people's self-confidence in the excellent traditional culture, activating the new kinetic energy of national regional non-legacy in the development of industry, and cultivating cultural soil for the dissemination of non-legacy in national regions in the new era, and the development of cultural soil [4]. Under the strategic background of rural revitalization, the digital protection of national regions' NON-heritage needs to start from new application scenarios, start from serving the contemporary, and explore the practical path of digital protection of national regions' NON-heritage from a new perspective [5-6].

In recent years, cultural tourism has gradually become a new form of tourism. Nonheritage, as an important carrier carrying national deposits and history, has a very rich cultural gene. The combination of non-heritage and tourism has become the most important part of cultural tourism [7]. Non-heritage is characterized by immateriality; how to integrate non-heritage culture, customs, and skills organically into tourism is a great challenge. At present, the new round of information technology represented by virtual reality and big models has entered the inflection point, and non-heritage tourism, with the help of virtual reality and other technologies, will expand the huge innovation space [8].

Intangible cultural heritage (ICH) is an important social resource and economic development resource in China's ethnic regions. Reasonable and effective protection and utilization of ICH is crucial to the development of ethnic areas and is an important means to achieve rural revitalization in ethnic regions. Plaster et al. illustrate the risks associated with the public exhibition of cultural artifacts, which both jeopardize the holders and authors of the artifacts while potentially affecting the inheritance of cultural heritage for future generations [9]. Silvia, D. et al. describe a senior citizen-driven online archival record of cultural heritage, which facilitates the integration of older adults into online socialization based on digital media technologies and also facilitates the dissemination and preservation of cultural heritage digitally [10]. Hannewijk, B. et al. stood for the popular vision. They designed a framework for the digital assessment of NRM in order to search for NRM and create it as a crowdsourced mobile program to facilitate its transmission and dissemination [11]. Atecaamestoy, V. et al. assessed the characteristics of groups participating in cultural heritage and pointed out that education level and economic power are highly correlated with participation in cultural heritage [12]. Kuo, C. C. et al. introduced and analyzed the logic and implementation of Taiwan's legislation related to underwater heritage and discussed the legal provisions of the UCHA, noting that they were mainly borrowed from the U.S. marine conservation-related laws [13]. Aka, Sümeyye. et al. addressed the significance of cultural heritage as an important hub linking the past, the present, and the future, which is of great importance for future generations. Therefore, it is important to develop multi-channel methods of preservation and transmission, such as digitalization, while preserving the physical and cultural heritage [14]. Roubal, P. revealed the 19th-century Wilhelm's property heritage and the conflict of urban planning in the context of neoliberalism, which is rooted in the spillover of socio-political and cultural struggles [15]. Qin, R. J. et al. used Nalu village in China as a case study and found that the cultural heritage and historical resources promote the economic tourism of the village to establish a well-known and distinctive signature, as well as increase the villagers' economic incomes and the pride of the residents [16].

In this paper, we first sort out the purpose of digital protection of traditional non-heritage culture, analyze the demand for the digital design of non-heritage culture from three dimensions: physical culture layer, behavioral culture layer, and spiritual culture layer, and discuss the effectiveness of the application of virtual reality technology in the digital protection of traditional non-heritage culture. Secondly, based on PHP technology, MySQL database, and Apache server, Zend Studio is used as the development tool. Virtual reality technology is combined to design a traditional NRH culture digital protection platform. Using VR technology combined with the PAT model and 5W communication model, the immersion experience model and display communication model of traditional non-heritage culture were established. To digitize non-heritage culture, this paper utilizes 3D laser point cloud acquisition technology to reconstruct it in 3D. It improves the accuracy of reconstruction by aligning the point cloud with an ICP algorithm. The purpose of this paper is to analyze the performance and application of the traditional non-heritage culture digital protection platform proposed in this paper to achieve the digital development of traditional non-heritage culture.

## **2 Demand for digital preservation of traditional non-heritage culture**

In the 21st century of rapid economic development, with breakthroughs in the field of high technology and the emergence of various new products, the inheritance and development of intangible cultural heritage have been impacted. The problem of transmission breaks has emerged, and many intangible cultural heritage projects that rely on the dissemination of artisans are facing an existential crisis or even the danger of imminent disappearance. Virtual reality technology, as an innovative force, can extract cultural elements from intangible cultural heritage and change the display form of intangible cultural heritage by shaping the virtual interactive space. It is associated with folk culture, performing arts, and traditional skills, bringing people diverse interactive experiences. In view of this, we should take the initiative to explore the innovative path of interaction design integration between virtual reality technology and traditional intangible cultural heritage to promote the digital protection and creative application of intangible cultural heritage projects.

### **2.1 Purpose of Digital Preservation of Non-Heritage**

Three aspects can be broadly divided into the purpose of using digital technology to protect non-heritage. On the one hand, it is to record and preserve all kinds of information about the non-heritage ontology by using digital collection and storage technology, so as to provide a guarantee for the complete protection of non-heritage. Three-dimensional data scanning, shadow and video filming, image capture, voice file recording, and the collection of physical objects are all part of this process. The second objective is to preserve and virtualize information on non-heritage cultural scenes, production processes, cultural spaces, and other related topics. Through digital restoration and reproduction technologies, we aim to support the effective inheritance of non-heritage. The third objective is to provide a platform for the extensive sharing of non-heritage materials by utilizing digital display technology and media dissemination technology.

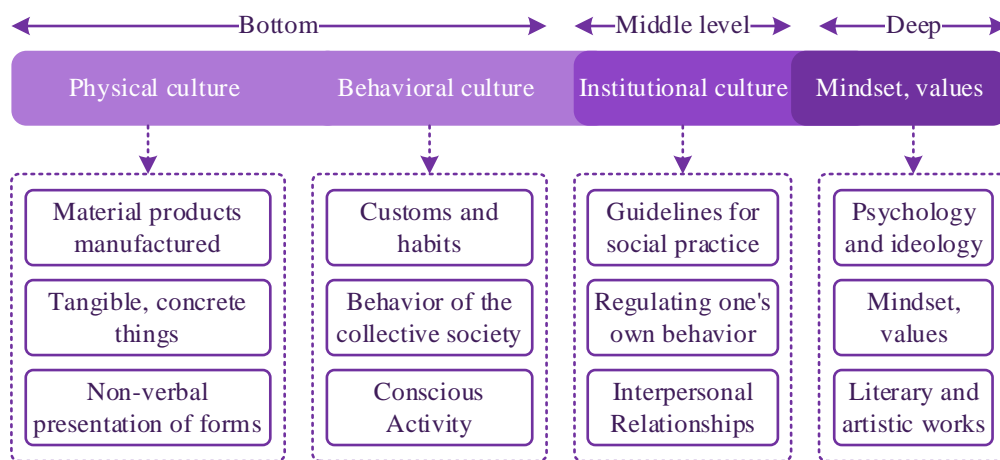
The digital protection of non-heritage should be roughly divided into three stages. One is the investigation and scientific research on the cultural resources of non-heritage ontology after clarifying the purpose of non-heritage protection, which is the premise of scientific digital protection of non-heritage. The second step is to set the goal of digital protection of non-heritage and select the corresponding digital technology platform and means. The third step is the technical realization of digital protection for non-heritage content.

The digitized materials of non-heritage are collected by way of digital collection from non-heritage entities, and what we have to do is to optimize the preservation and presentation of the physical

resources. At the same time, through the effective dissemination of digital resources, we can “amplify” and “extend” the value of digitization of non-heritage. In order to realize the return of traditional intangible culture, the spiritual core of non-legacy can naturally be popularized, influenced, and inherited.

## 2.2 Design of digital non-heritage culture

There have been no generations of non-heritage bearers who have passed down non-heritage culture to the present day. From a philosophical point of view, culture is divided into four levels, i.e., Physical culture, institutional culture, behavioral culture, and mental culture. According to the above classification, the author believes that the inheritance of non-heritage culture can be divided into three levels, the specific performance of which is shown in Figure 1, mainly for the physical culture layer, behavioral culture layer, and spiritual culture layer, which must be taken into account when designing the digital protection platform for non-heritage at the same time.



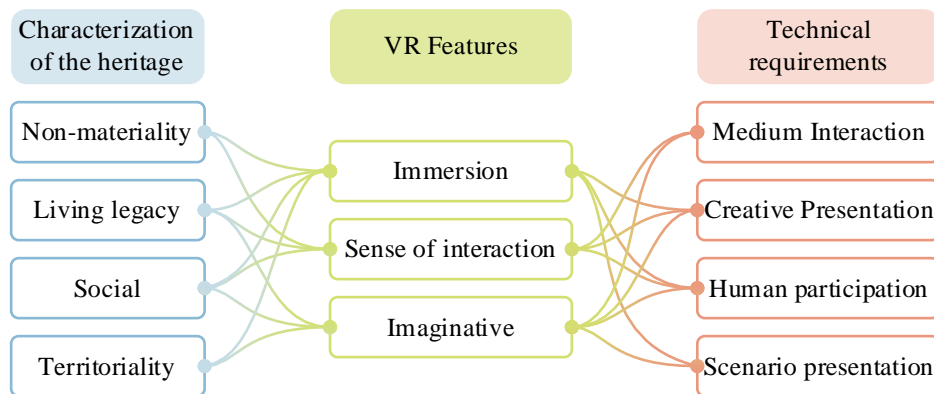
**Figure 1.** Digital non-heritage design hierarchy

- 1) The physical cultural layer refers to cultural things with material entities created and used by human beings in production and life. Among the digitization platforms of NRLs, the characteristics and visual forms of materials should be fully considered in order to preserve the original appearance and characteristics of NRLs. The characteristics of the materials should be taken into account when digitizing and capturing, and digital technology can accurately capture and reproduce various details and features of the objects.
- 2) The behavioral culture layer is the agreed-upon behavioral patterns manifested in social customs, traditional rituals, cultural mores, and so on. In the process of digital acquisition, attention should be paid to the details of behavioral movements and gestures in the cultural heritage. Hence, as to more accurately present the unique characteristics of these behavioral cultures in digital processing.
- 3) The spiritual culture layer is an indispensable part of human society and culture, which forms a series of ways of thinking, values, and aesthetic interests. The design of NRL digitization in the spiritual culture layer refers to the digital presentation and dissemination of the values and spiritual connotations behind NRL culture, including the digital presentation of the philosophical thinking, artistic aesthetics, values, and national spirit of NRL culture.

### 2.3 Feasibility of Virtual Reality Technology

Virtual reality (VR) has been rapidly developed, and virtual technology with immersive, interactive, and imaginative features has strong advantages in non-heritage inheritance. For the digital protection and inheritance of non-heritage culture, it is not only necessary to pay attention to the application of emerging technologies, but also to consider the characteristics of this type of non-heritage and the feasibility of technology application.

The feasibility of the application of VR technology in the digital protection of non-heritage culture is shown in Figure 2, which relies on VR technology to dynamically capture the immateriality of non-heritage culture, realize the living inheritance and innovative presentation of non-heritage culture, and promote the participation of the community and the regional multi-scenario presentation. Scenarios.



**Figure 2.** Feasibility of virtual reality technology

In the digital protection of non-heritage culture, VR technology offers a new way of cultural experience through immersion, interactivity, and imagination. It can create realistic, three-dimensional, and creative cultural scenes to help users immerse themselves in them. In addition to this, virtual NRM cultural products can be simulated based on the reality of already existing physical objects. They can also realize the redesign of NRM cultural products, which, more innovatively and imaginatively, can adapt to and arouse the participation of a wider group of people.

## 3 Digital Protection Platform for Non-Heritage Combined with VR

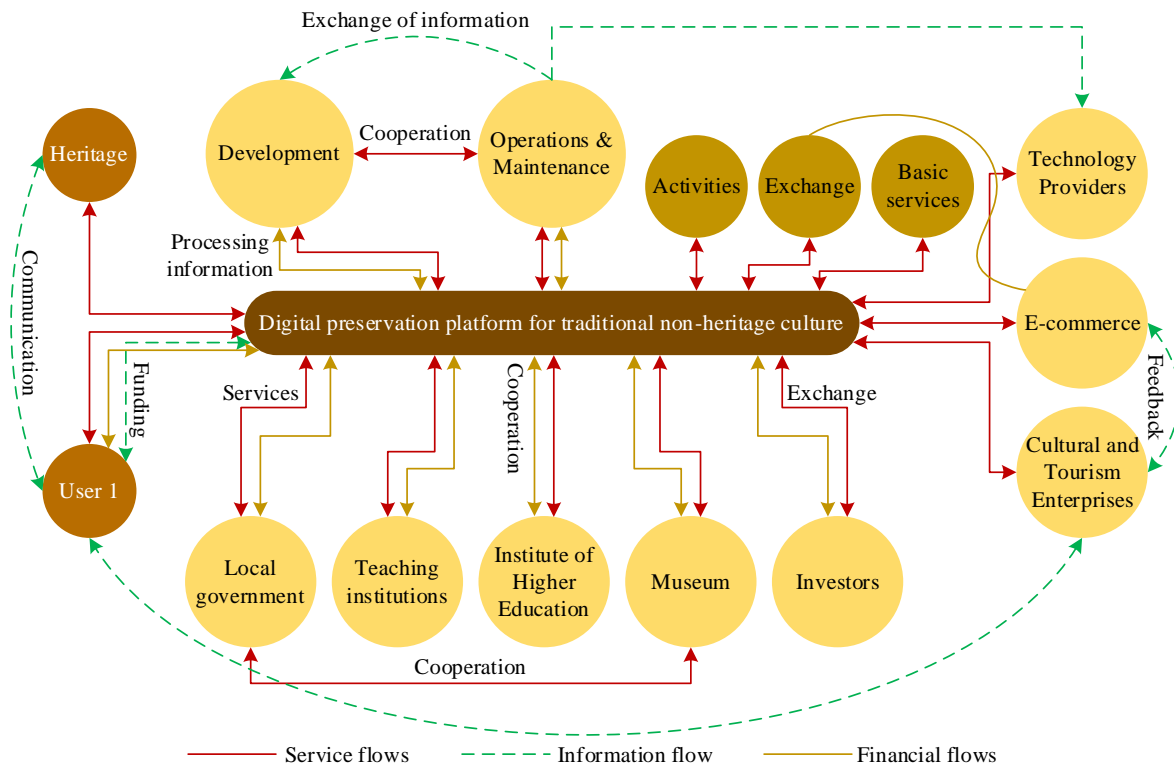
With the development of the times and the progress of society, some skills of Chinese traditional intangible cultural heritage are facing the plight of being on the verge of being lost in the process of inheritance. In this context, in order to promote the creative transformation and innovative development of intangible cultural heritage and realize the sustainable development of intangible heritage, we must carry out the digitization construction of intangible heritage. Constructing a digital protection platform for traditional intangible cultural heritage using VR technology can help promote the healthy and orderly development of the cause of protecting intangible cultural heritage.

### 3.1 Framework for a platform for the digital preservation of non-heritage

#### 3.1.1 Digital Protection Platform Architecture

The digital protection platform of non-heritage culture is designed based on the way of PHP technology, MySQL database, and Apache server, with Zend studio as the development tool, using

Photoshop CS6 technology to modify the web page, supplemented by CSS technology. The basic structure of the digital protection platform for non-heritage cultures is shown in Fig. 3, and the system is based on the Web application of object-oriented programming. This system was designed and implemented to meet the needs of protecting and promoting Jingdezhen's intangible cultural heritage. It adopts computers to carry out intangible cultural heritage service, management, and display, which improves the convenience and safety of management, etc. Also, it adapts to the characteristics of the high-speed development of information technology in today's society.

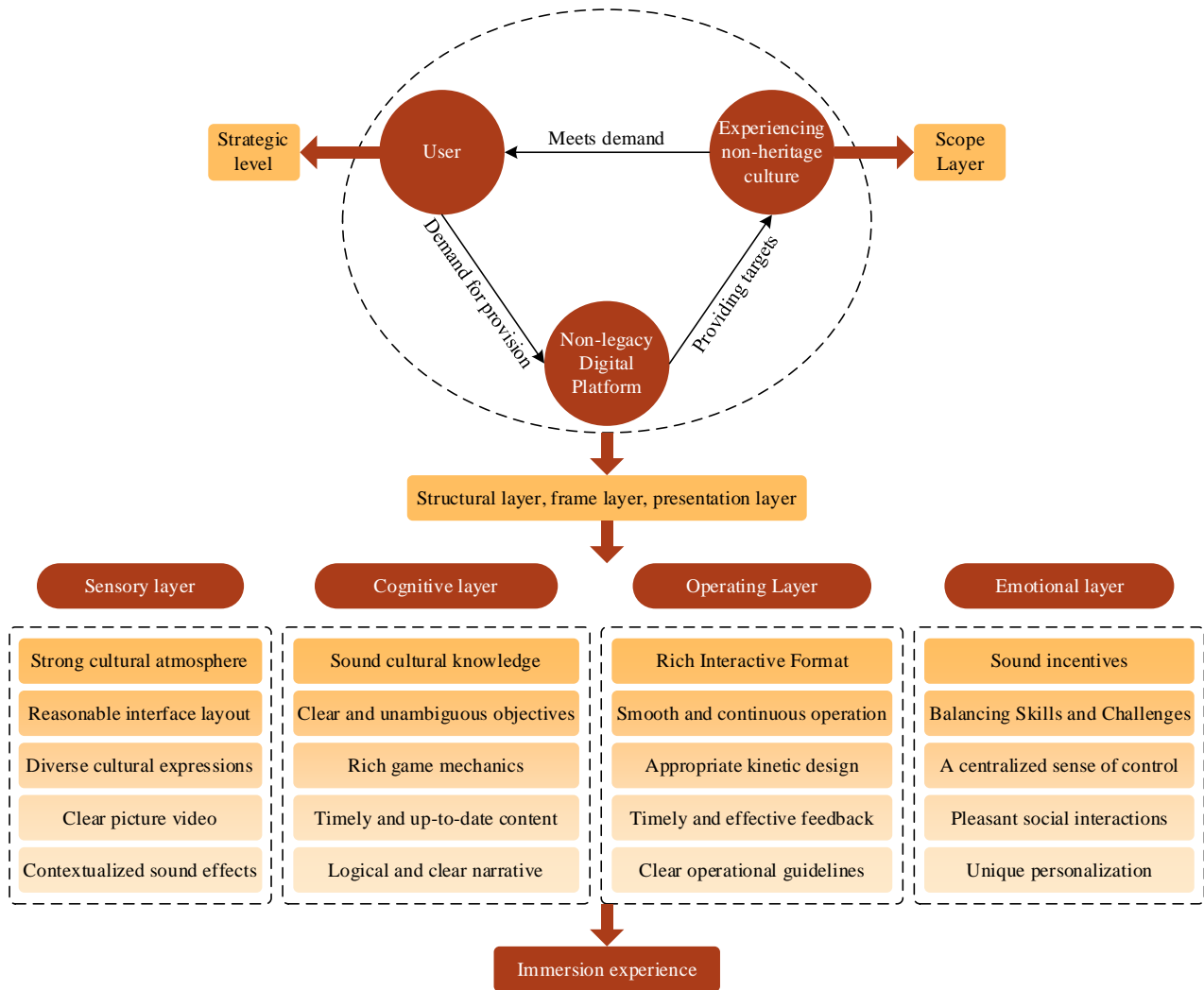


**Figure 3.** Non-legacy digital protection platform

In the process of construction and application of the digital protection platform for non-heritage culture, it is necessary to integrate and coordinate resources and strengths from different fields and different institutions, including inheritors, technicians, and cultural industries. Good cooperative relationships are established through service design methods to realize collaborative innovation in order to improve the success and efficiency of digital protection and inheritance in non-heritage cultures. Therefore, this study opens the information-receiving channel of young audiences, enhances communication efficiency, and expands the communication area by constructing a digital protection platform for NRH culture and utilizing the digital protection and inheritance, display, and education platform.

### 3.1.2 Models of non-heritage Immersion Experience

For the traditional non-heritage culture digital protection platform established in this paper, it needs to provide users with a real immersive experience to promote users to feel the charm of conventional non-heritage culture. As a result, this paper takes the PAT model as the basis. It combines VR technology with the digital protection platform of non-heritage culture to establish an immersion experience model, whose basic structure is shown in Figure 4. Relying on the immersion experience model to help users realize sensory interaction in terms of hearing and touch so that users can better produce immersion experiences.

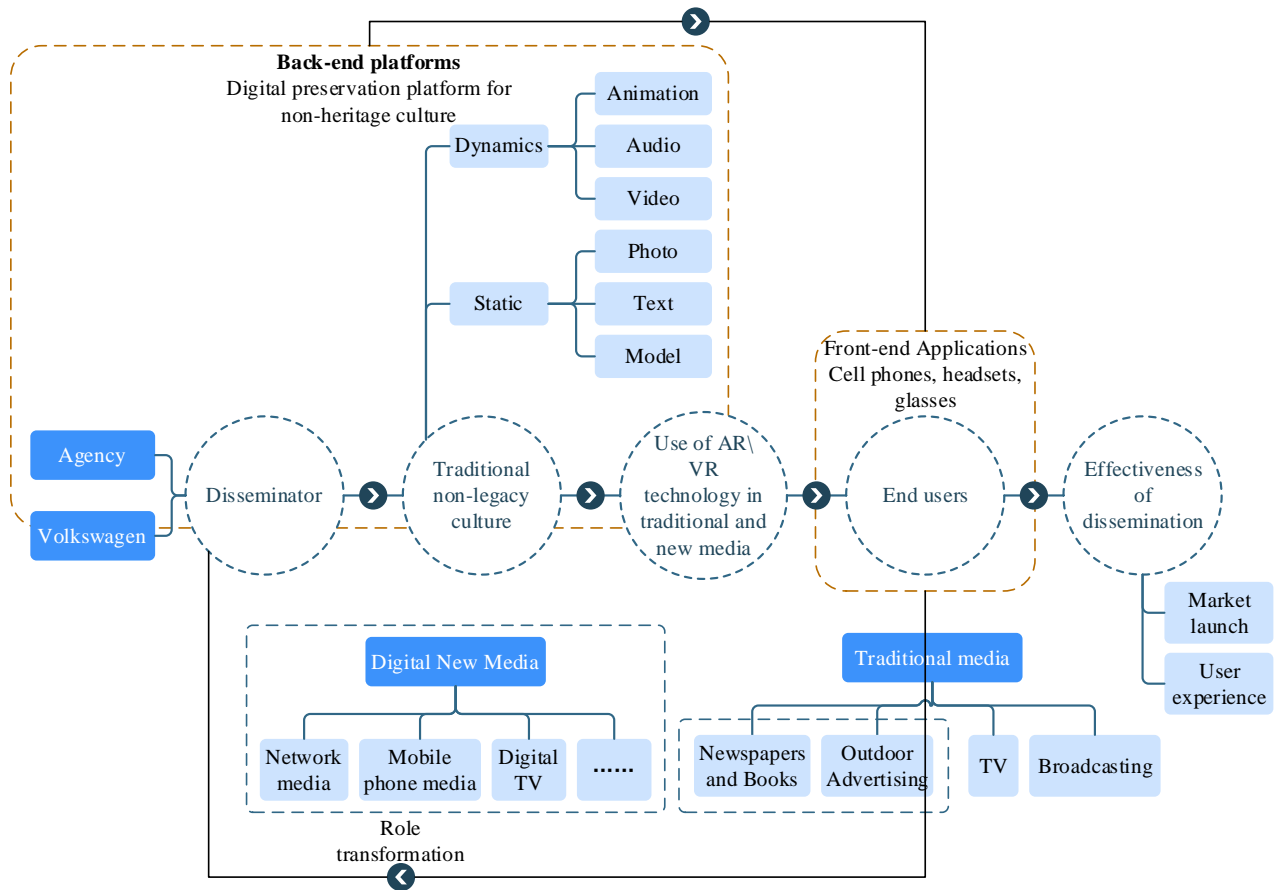


**Figure 4.** Unimpressed Immersive Experience Model

Emotional design can bring users a pleasant experience, and emotional design should be considered when designing the digital protection platform for non-heritage, combined with the user-centered design concept to make users get an emotionally rich interactive experience and meet their emotional needs. When users enter the digital platform for non-heritage purposes, they should have a full sense of control during the process of using it and be able to clearly understand their operations and goals. In addition, the personalized customization in the model can promote the living inheritance of non-legacy culture and allow users to create their unique creations.

### 3.1.3 Models for the dissemination of NRM displays

For the traditional non-heritage culture digital protection platform, realizing the inheritance and development of non-heritage culture is its core requirement, and the display and dissemination of non-heritage culture based on the digital platform is aimed at further expanding the diversity of non-heritage culture display and dissemination channels and boosting the high-quality inheritance of non-heritage culture. Thus, based on the 5W communication model and KANO demand model, this paper establishes a digital display and dissemination model of traditional non-heritage culture based on VR technology, as shown in Figure 5, which mainly contains five contents: disseminator, non-heritage culture content, dissemination carrier, and medium, user and dissemination effect.



**Figure 5.** Non-legacy display propagation model

For the information media, users expect a stronger sensory experience in VR scenes, and presenting information in the form of motion effects, video, and audio will increase user satisfaction. In contrast, pictures and text information are the basic needs, mainly serving as auxiliary explanations. In terms of carrier terminals, users expect to provide cell phone applications and expect them to be combined with traditional paper media. Simple and technological interfaces can be experienced anytime and anywhere. To offer mobile applications, users expect to integrate with conventional paper media when the user needs to provide purchase information and channels to offer exploratory scenarios will greatly improve the user experience and thus enhance the dissemination effect.

## 3.2 Acquisition of digitized 3D data of NRHs

### 3.2.1 Digital 3D Reconstruction of Non-Heritage

In the traditional non-heritage culture digital protection platform, it is the use of three-dimensional laser point cloud data acquisition and processing technology to initially obtain the relevant point cloud data based on the traditional non-heritage culture digital image feature vector, combined with the empirical knowledge among the targets of non-heritage culture to form the learning samples of the non-heritage culture digital image features. Thus, the power spectrum of the three-dimensional image is calculated, the difference information in the image reconstruction is fused, and the probability distribution function of the target traditional non-heritage culture in the image is obtained, based on which the reproduction of the conventional non-heritage culture digital image in the non-heritage culture digitization and protection platform is completed. The following describes the specific steps:

Assuming, by  $\{v_1, v_2, \dots, v_s\}$  represents  $S$  feature vectors in the 3D image reconstruction process, and the part of the vectors is divided into  $q(1, q, s)$  groups, and each group contains  $s_i$  vectors and is described by  $\{v_1^i, v_2^i, \dots, v_s^i\}$ , the 3D non-heritage culture digital image feature learning samples are formed by using Eq. (1). Namely:

$$R(r) = \frac{\{v_1, v_2, \dots, v_s\} \otimes q(1, q, s)}{\{S \times s_i\} \otimes \{v_1^i, v_2^i, \dots, v_s^i\}} \quad (1)$$

Assuming, the  $s_i$  vector of image features is defined as the input of the neural network, and the  $n$  initial trust level of the image feature information ( $cF \in [0,1]$ ) is taken as the output of the neural network, the 3D digital image power spectrum of the traditional NRM culture can be expressed as:

$$F(u, v, m)e^j = (cF \in [0,1]) \otimes \frac{|Y(u)| e^{j\theta(u,v,w)} \otimes R_y(i, j, k)}{n \times \theta(u, v, w) \otimes s_i} \quad (2)$$

Where  $Y(u)$  represents the Fourier transform process of the image,  $\theta(u, v, w)$  represents the spoke angle,  $e^j$  represents the range of values of the spoke angle, and  $R_y(i, j, k)$  represents the real number domain of the image after the Fourier transform.

Assuming that by  $T$  represents the acquisition period of the image information, the image feature information fused with the difference information of the  $i(1, i, q)$  th neural network in the  $(k-1)T$  th moment in the 3D image reconstruction,  $m_{i,1}(k-1)$  represents the difference information fused with the difference information of the 8th neural network, the difference information fused in the image reconstruction by using Eq. (3), then:

$$m_{i,1}(\theta) = \frac{(k-1)T \otimes T \otimes m_{i,j,k}(kT) \times \theta_{i,k}}{(g+1) \times m_{i,1}(k-1) \times i(1, i, q)} \otimes m_j^{\theta+1}(k) \quad (3)$$

Where,  $m_{i,j,k}$  represents the fusion state of each difference information at the  $kT$  time,  $\theta_{i,k}$  represents the unknown degree of each difference information, and  $m_j^{\theta+1}(k)$  represents the difference information fusion result of the first  $g+1$  neural network.

Assuming that the basic probability assignment function of the  $j$  th target is represented by  $m_j^q(k)$  during the  $kT$  time period in the 3D image reconstruction process, the decision probability assignment function of the target elements in the traditional NRM culture image is:

$$m_j(k) = \frac{m_{i,1}(\theta) \pm m_j^q(k)}{F(u, v, m)e^j} \theta(k) \otimes R(r) \quad (4)$$

Where  $\theta(k)$  represents the unknown degree of information acquired in  $kT$  time.

Suppose, by  $\lambda(x, y)$  represents the 3D image function reconstructed using the projection value,  $u(p)$  represents the 3D feature space of traditional non-heritage culture images, and  $E(\delta)$  represents the convolutional back-projection of traditional non-heritage culture image features. Then,

the digital image authenticity replication of traditional non-heritage culture is accomplished by utilizing Eq. (5). Then:

$$\int h(\xi) = \frac{E(\delta) \otimes \lambda(x, y)}{u(p)} \otimes \frac{E(\delta) * \Phi(\square)}{\Gamma(\alpha)} m_j(k) \tag{5}$$

Where  $\Phi(\square)$  represents the angle between two adjacent azimuthal maps and  $\Gamma(\alpha)$  represents the distance between two adjacent equally spaced parallel rays.

### 3.2.2 ICP-based point cloud alignment

In section 3.2.1, the 3D laser point cloud acquisition technology is used to realize the acquisition of traditional non-heritage culture digitized images. In the process of 3D reconstruction of traditional non-heritage culture digitized images, it is necessary to effectively align the 3D reconstructed non-heritage culture digital images with the point cloud data in order to ensure the digital restoration of non-heritage culture. Therefore, this paper introduces the iterative closest point algorithm (ICP) for iterative alignment, which realizes the alignment of two point cloud sets by finding the corresponding point pairs and calculating the optimal rigid-body transformation parameters between the corresponding point pairs.

The ICP algorithm’s basic principle is as follows:

- 1) Initialize the point cloud. Set the source point cloud as  $P$  and the target point cloud as  $Q$ .
- 2) Search for corresponding point pairs using the exhaustive search method. For each point  $p_i$  in the source point cloud, search the corresponding point  $q_i^k$  in the target point cloud to form the corresponding point pair  $(p_i^k, q_i^k)$ .
- 3) Calculate the rigid body transformation parameters. The quaternion method is used to calculate the rigid-body transformation parameters  $R^k$  and  $T^k$  based on the principle of minimizing the objective function:

$$f(R^k, T^k) = \frac{1}{N} \sum_{i=1}^N \|q_i^k - (R^k p_i^{k-1} + T^k)\|^2 \tag{6}$$

- 4) Perform rigid-body transformation. Using the rigid-body transformation parameters  $R^k$  and  $T^k$ , perform a rigid-body transformation on the source point cloud  $p'_k$  to obtain a new source point cloud  $p'_{k+1}$ . Then:

$$P'_{k+1} = R^k P'_k + T^k \tag{7}$$

- 5) Calculate the point-to-point distance  $d_k$  after the rigid body transformation. Then:

$$d_k = \frac{1}{N} \sum_{i=1}^N \|p_i^k - q_i^k\| \tag{8}$$

$$d_{k+1} = \frac{1}{N} \sum_{i=1}^N \|p_i^{k+1} - q_i^{k+1}\| \quad (9)$$

- 6) Iteration termination judgment. Set the threshold  $\varepsilon$ , if  $d_{k+1} - d_k < \varepsilon$ , or the maximum number of iterations  $k_{\max}$ , then stop iteration; otherwise, repeat the above process.

The Iterative Nearest Point (ICP) algorithm is commonly used for point cloud alignment in point cloud fusion processing. The algorithm has various advantages, which are summarized as follows:

- 1) The ICP algorithm can be applied to diverse and complex practical scenes.
- 2) The ICP algorithm has a good alignment effect.
- 3) The ICP algorithm does not need to extract feature points, and it can directly process the point cloud data.
- 4) The alignment effect of the ICP algorithm is good in the case that the initial position of the point cloud has a good attitude.

## 4 Application Practice of Digital Conservation Platform for Non-Heritage

The development of traditional culture and the development of the times have always existed in a certain degree of contradiction; the high-speed development of new crafts, new technologies, and new equipment gradually replacing the traditional manual, the rapid growth of modern civilization, the gradual dilution of the concept of inheritance, as well as the protection of a relatively single mode of non-hereditary inheritance crisis continues to aggravate. VR technology, by virtue of its characteristics, through three-dimensional reproductions, effectively breaks through time and space limitations to provide the audience with a traveling experience so as to realize the non-hereditary cultural inheritance. Thus realizing the inheritance of non-heritage culture. At the same time, with the help of the Internet, blockchain, and other new technological means, the storage of VR three-dimensional elements to realize the digital protection of the non-heritage, creating a good environment for the dissemination of traditional Chinese culture and dissemination mode, which greatly facilitates the dissemination, security, and inheritance of non-heritage culture.

### 4.1 Validation of the platform for the digital preservation of non-heritage

#### 4.1.1 Performance testing of the NRM platform

Platform system testing is an important part of software development as it helps to find and fix any errors that may have been missed during the development process. Without system testing, there is no way to ensure that the platform is able to meet the needs and expectations of the users. Before the system is officially launched and put into use, it helps to improve the quality of the software by doing an overall performance test of the system to ensure that the behavior of the software features in various scenarios is as expected.

In this paper, we use Apache JMeter to perform performance testing on a traditional non-legacy culture digital protection platform. JMeter can perform performance testing on the target service with concurrent threads to analyze system performance under different loads and test intensities. In this performance test, six test scenarios of 500, 2000, 4000, 6000, 8000, and 10000 concurrent threads are

set up to control the performance of the traditional non-heritage culture digital protection platform under different concurrency, and each test scenario is run for 1 minute. Using JMeter to execute the concurrency performance test results in a change in TPS, as shown in Figure 6.

The figure can be seen more intuitively that the number of concurrencies of 500 can not give full play to the performance of traditional non-heritage culture digitization and protection platforms; TPS is about 69,500 per second when the number of concurrencies increased to 2000, TPS appeared to rise, rose to about 94,300 per second. When the number of concurrencies further increases, the non-heritage culture digital protection platform is overloaded, and the TPS has a downward inflection point; when the number of concurrencies rises to 10,000, the TPS shrinks to about 35,000 per second, so it can be speculated that the optimal operating environment for the traditional non-heritage culture digital protection platform is concurrency within 2,000, which can achieve the maximum throughput.

In addition, it can be seen that the TPS fluctuation between the beginning and the end of each round of testing is very large; this is because at the beginning of each round of testing, it is necessary to turn on the multi-threading, the highest test scenario in this paper has 10,000 threads, which takes up a lot of computer resources, and the opening of threads needs to consume a certain amount of time, so there is a low TPS performance at the beginning of each round of testing. At the end of the test, it is also necessary to close multiple threads one by one, so at 6000 concurrent threads or less; there is a sudden drop in TPS at the end of each round of testing. A sudden increase in TPS occurs at the end of the test with more than 6000 threads, which is not the case when testing with less than 6000 threads. This is because when there are more than 6000 threads, the excessive number of threads makes the CPU consume computational resources on thread switching, and when the number of threads is lowered, the actual execution rate of the threads is improved, and the TPS increases suddenly.

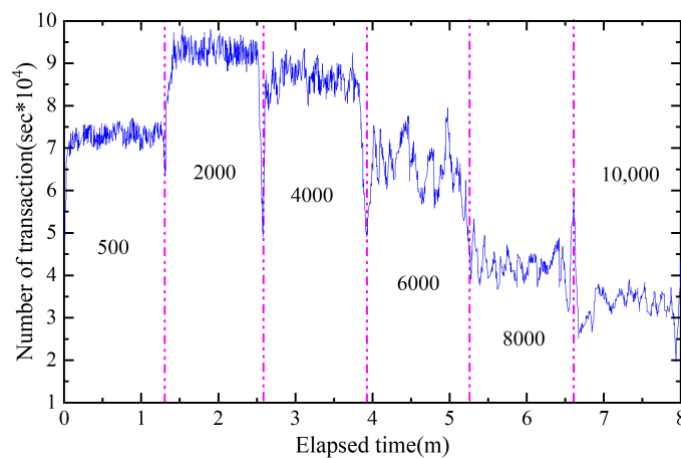


Figure 6. JMeter Test TPS

#### 4.1.2 Effectiveness of Non-Religious Point Cloud Alignment

In order to verify the feasibility of the traditional non-heritage culture digital image alignment algorithm proposed in this paper, the point cloud data of the conventional non-heritage culture digital image is taken as the experimental object. The RMSE is chosen as the evaluation index, and the algorithm in this paper is compared and analyzed with the algorithms of SAC+IA, NDT, and IA+NDT. Figure 7 displays the results of the alignment accuracy of traditional non-heritage culture digital images.

In the course of 10 alignment experiments of digital images of traditional non-heritage culture, the alignment errors obtained by the ICP alignment algorithm proposed in this paper are lower than those of SAC+IA, NDT, and IA+NDT algorithms. At the same time, according to the folding line direction, it can be seen that the alignment error obtained by the alignment algorithm proposed in this paper for the digital images of traditional non-heritage culture is not higher than 0.30mm. In contrast, the alignment errors obtained by the other algorithms are higher than those of this paper's method. The average accuracy of traditional non-heritage culture digital image alignment obtained by this paper's algorithm in twenty experiments is 0.294mm, which is 51.82%, 54.23%, and 56.43% lower than SAC+IA, NDT, and IA+NDT algorithms, respectively. This indicates that the use of an ICP algorithm can achieve accurate matching of traditional NRH digital images and provide support for the generation of NRH digital images in the NRH digitalization platform.

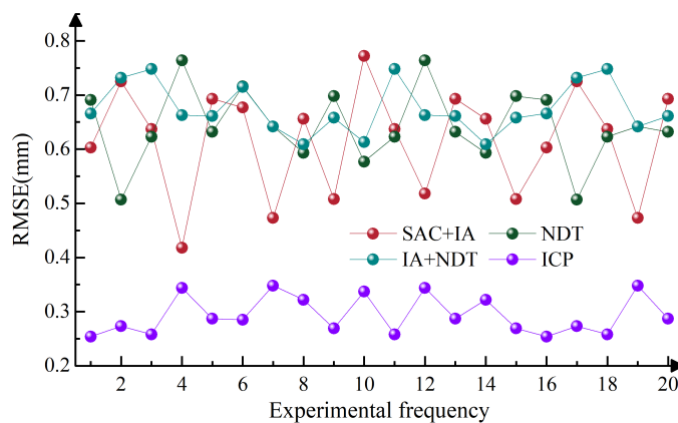


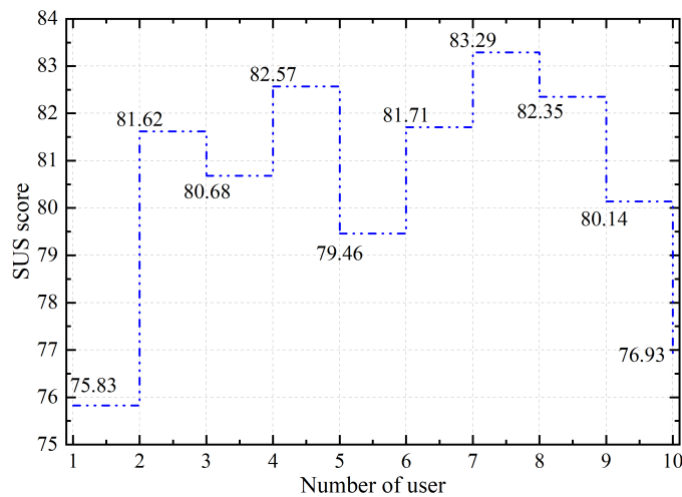
Figure 7. Non-legacy point cloud matching effect

## 4.2 Application of the platform for the digital preservation of non-heritage

### 4.2.1 Digital Platform Usability

Usability testing is done during the early or middle stages of product development to identify usability issues and enhance optimization by observing typical users completing typical tasks of the product. The usability test of the digital protection platform for non-heritage culture involved 10 users being chosen to experience the VR headset and VR handle and complete the corresponding tasks to assess its usability. To ensure an intuitive user experience, this paper selects the SUS system usability scale to analyze, adopts the Likert five-level scale to quantify the data, and multiplies the conversion factor to calculate the final score. Figure 8 shows the user's SUS scale score.

In the overall usability test, the average SUS scale score of the 10 users was 80.46, so the users were satisfied with the usability of the platform for digitization and protection of non-heritage culture as a whole. Still, according to the process of the user's completion of the tasks as well as the later interviews, there are some directions of improvement that can be drawn. First, the completion icon for safety preparation is not obvious. Instead, the corresponding button lights up and has a zoom animation to prompt the user after the operation has been completed. In order for users to complete the collection of digital images of non-heritage culture in a more portable way, it is important to simplify the pattern and upgrade the technical equipment. The adjustment of the position of the wearable device model for safety preparation is too deep. To ensure compatibility with the human-machine size, enhance the tilt angle and viewing distance of the UI interface.



**Figure 8.** The SUS scale score of the user

#### 4.2.2 Digital Platform Sensory Experience

The traditional non-heritage culture digital protection platform mainly shows conventional cultural values. It uses values of non-heritage culture, relying on virtual reality technology to enrich the user’s sensory experience when browsing non-heritage culture in the digital platform. Therefore, this paper designed the corresponding questionnaires from four dimensions of visual perception, auditory perception, tactile perception, and spatial perception, and quantified them with the Likert five-level data, in which A, B, C, D, and E are very satisfied, satisfied, average, dissatisfied and very dissatisfied, so as to clarify the real experience of the NRL culture digital protection platform for users. Users’ evaluation of the digital protection platform for non-heritage culture is shown in Figure 9.

As can be seen from the figure, the users’ satisfaction with the sensory experience of the traditional non-heritage culture digital protection platform is high, with the proportion of users who are generally satisfied and above reaching 94.87% and the average proportion of very dissatisfied users is only 1.26%. Among the four kinds of sensory experience, the proportion of users who were very satisfied with the visual sensory experience reached 53.42%, which was 4.78, 17.85, and 9.53 percentage points higher than that of the auditory sensory experience, tactile sensory experience, and spatial sensory experience respectively. The digital protection platform of traditional non-heritage culture carried out on the basis of virtual reality technology is to perceive the shape and color of the digital images of non-heritage culture through vision. The virtual space provides users with a sense of immersive and real experience, provides users with more visual expression, and promotes the enhancement of users’ visual perception. In addition, through the digital processing of traditional non-heritage culture, the conventional diversified and unique non-heritage culture of China is displayed in the virtual space, which makes the non-heritage culture show its beauty, provides users with a digital space full of non-heritage culture, fully meets the users’ needs for non-heritage culture awareness and understanding, and provides reliable support for the digital protection and inheritance of traditional non-heritage culture.

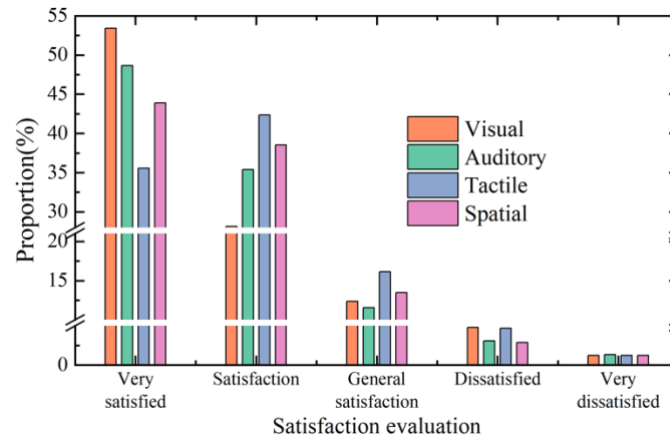


Figure 9. Sensory experience of digital platform

## 5 Conclusion

On the basis of analyzing the demand for digital protection of traditional non-heritage culture, this paper designs a traditional non-heritage culture digital protection platform by combining PHP technology, MySQL database, Apache server, and virtual reality technology, and utilizes 3D laser point cloud acquisition technology combined with ICP algorithm to carry out the non-heritage culture digital image point cloud alignment. For the digital protection platform proposed in this paper its application has been verified, and the conclusions are as follows:

- 1) From the performance test results of the non-heritage digitization platform, when the number of concurrent threads is within 2,000, the platform's transaction response per second can be up to about 94,300, and the platform's TPS decreases by about 35,000 per second after exceeding 10,000 concurrent threads. By achieving the maximum throughput within 2000, the traditional non-heritage culture digitization and protection platform designed in this paper can maintain the stability of its users.
- 2) In terms of the alignment accuracy of digital images of non-heritage culture, the point cloud alignment implemented based on the ICP algorithm yielded an average accuracy of 0.304mm in ten experiments for the alignment of digital images of traditional non-heritage culture, which is 51.82%, 54.23%, and 56.43% lower than that of SAC+IA, NDT and IA+NDT algorithms, respectively. Using the method in this paper, high-precision digital images related to traditional non-heritage culture can be obtained, which provides a guarantee for the digital protection of non-heritage culture.
- 3) In terms of the application of the platform for digitization of non-heritage culture, the average SUS usability score of users is 80.46, and the various functions of the platform can help users provide reliable assistance in understanding the knowledge related to non-heritage culture. In addition, users are most satisfied with the visual experience of the platform, and the digital presentation of non-heritage culture enriches users' visual perception and provides a new guiding direction for the visual expression and innovative inheritance of non-heritage culture.

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