Computational Technologies on Modeling of Museum Interactive Virtual Display Based on User Experience

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In order to solve the problems of the traditional museum interactive virtual display modeling methods such as poor clarity, low user satisfaction, and long interactive response time, a museum interactive virtual display modeling method based on user experience was proposed. The museum information collection system is set up to collect 3D point cloud data of exhibits by using the system, and the 3D point cloud data are denoised by the moving least squares method. The museum building data and denoised 3D point cloud data are integrated, and all point cloud data are registered. According to the registration results, the interactive virtual display model of the museum is preliminarily constructed, and the user experience model is used to adjust the parameters of the display model to realize the interactive virtual display modeling of the museum. The simulation results show that the proposed method has a high definition of the interactive virtual display of a museum, the average user satisfaction is 9.45, and the interactive response time is always below 0.4s, which fully verifies the superiority of the proposed method.

1. Introduction

Nowadays, with the further development of virtual reality technology, the traditional museum display mode has been impacted to a certain extent, resulting in its development into a bottleneck [1]. Due to the limitations of low technical level, limited exhibition space, and other aspects, the traditional museum display mode is unable to absorb the current development experience and display technology, resulting in the museum’s popularity and the number of visitors being greatly reduced. The current form of museum display is mainly brand and image to explain tourists’ names and historical information, and the monotonous display mode is difficult to stimulate the interests of tourists. As time goes by, it leads to a sharp decline in the number of museums, making it difficult for some excellent historical culture to be widely spread. In serious cases, the management of the museum falls into difficulties [2]. But at this stage, the rapid development of social economy led to further improve the level of science and technology, the virtual reality technology, and information technology under the condition of the rising, people increase gradually to the attention of the new technology, and visitors are no longer content to appreciate the display of the exhibits in the museum but want to explore more exhibits profound meanings behind. It is of great significance to design a new modeling method for interactive virtual exhibition of museums.

In light of the virtual display of these issues, the study in [3] proposes a virtual reality modeling method in a replica of the Terra Cotta Warriors, which is primarily based on the actual design parameters and the Terra Cotta Warriors museum, to set up a copy 3D model of the warriors museum in order to enhance the historical sense scene and improve user interactivity as the research target. In addition, the 3D model’s parameters are established and the 3D model is produced using the Unity3D virtual engine, allowing the replica terracotta soldiers to be shown and modeled. However, although this approach has a strong interactive impact after application, it has the flaw of poor user satisfaction, which is incompatible with the study’s objectives. In order to boost the museum’s virtual display impact, the
study in [4] developed a gesture recognition-based modeling technique for virtual museum displays. To build a 3D gesture model, to build a good model for Kalman filtering and sparse representation, and to optimise the 3D gesture model, the resulting museum exhibits show movement trajectory, and to realize the virtual museum display modeling method, the basic theory is first analysed and then combined with multiple sets of gesture data to establish the 3D space coordinate system. However, this technology has the issue of low museum display definition, and the practical application impact is poor. The study goal of reference [5] was to widen the museum display route and enhance the display impact of exhibitions using a museum scene display modeling approach based on the Unity3D virtual reality engine. To achieve the goal of improving the interactive level of the museum scene display, 3Dmax is used to create relevant 3D models based on the actual situation of the museum and its exhibits, lighting and material parameters in the 3D model are adjusted based on the actual scene, and human-computer interaction is realised using the Unity3D virtual reality engine. However, this strategy suffers from the practical issue of poor interactive reaction time, making it difficult to market broadly.

This work offers a museum interactive virtual display modeling approach based on user experience to address the disadvantages of the aforementioned museum interactive virtual display modeling methods, such as inadequate clarity, low user satisfaction, and lengthy interactive response time. This method’s general design plan is as follows:

1. Create a museum information gathering system, utilise it to collect 3D point cloud data of exhibits, and denoise the data using the moving least squares approach. All point cloud data are recorded, and the museum building data and denoised 3D point cloud data are combined.

2. The interactive virtual display model of the museum is preliminarily produced based on the registration results, and the user experience model is utilised to alter the parameters of the display model to get the final modeling results of the museum’s interactive virtual display.

3. Simulation tests are used to compare the clarity, user happiness, and interactive response time of various methodologies.

4. Come to a resolution and plan for the future.

2. Design of the Modeling Method for Museum Interactive Virtual Display

2.1. Museum Information Collection Based on 3D Laser Scanning. Because the 3D reconstruction is involved in the modeling process of the interactive virtual display of museums, it is necessary to use high-precision information collection equipment to collect the exhibit’s information. Therefore, a museum information acquisition system is built in this paper by using a two-dimensional linear laser scanner and a precise program-controlled 3D translation platform.

The system can realize automatic 3D scanning and data splicing of exhibits information, so as to obtain more accurate laser scanning data. The hardware of the system is mainly composed of six parts: DT-400E precise program-controlled 3D translation platform, LJV-7200 laser scanner, computer, vacuum loading sucker, limit device, and infrared photoelectric switch. The physical hardware of the museum information collection is shown in Figure 1.

The hardware components of the museum information collection system are as follows:

1. **LJV-7200 Two-dimensional Laser Scanner.** The scanner is one of the most important components of the museum information acquisition system. It is composed of a sensing head, a controller, and a power lamp. The supporting software is LJ-Navigator2 [6, 7]. It mainly uses the sensor head of the scanner to scan the X and Z coordinates of the exhibits and transmits the collected information to the computer through LJ-Navigator2, so as to lay a solid data integration for the subsequent interactive virtual display modeling of the museum. The laser scanner parameter settings are shown in Table 1.

2. **DT-400E Precision Program-Controlled 3D Translation Platform.** The translation platform primarily uses the teaching box to compile the system’s operation degree, in order to control the translation arm’s movement direction and the translation platform’s vacuum suction cup, to assist the system in completing the 3D scanning work of museum exhibits.

3. **Vacuum Suction Cup.** The vacuum suction cup is situated mostly on the translation platform. Placing the exhibits under test on the vacuum suction cup ensures that the exhibits under test do not shake during the translation platform’s movement, reducing measurement accuracy and hence improving 3D scanning accuracy and lowering measurement error [8].

4. **OS805 Infrared Photoelectric Switch and Limit Device.** This device’s major role is to create a link between the translation table and the computer in order to enhance laser scanning data transfer, guarantee that data is not lost, and increase data collecting accuracy [9].

5. **Laptop Computer.** We accept 3D scanning data of museum exhibits with a laptop and store them in memory and then use a laptop computer to stitch 3D scanning data and create interactive virtual display modeling of museum exhibits.

In this paper, XYZ spatial coordinate system is mainly used to represent the 3D coordinates of museum exhibits, where X represents the moving direction of the translation arm, Y represents the moving direction of the translation platform, and Z represents the elevation direction of the museum exhibits. The museum exhibits are placed on the vacuum suction cup in the translation platform, which can move freely along the Y direction, and the laser head can...
generate a wide F, indicating the translation unit along the X-axis, where \( \Delta x \) represents the length of the translation. The coordinates of a row in the \( F_k \) format can be expressed by the following formula:

\[
X_k = k \times \Delta x + x_i, \\
= k \times 0.1 \times i, \quad i = 1, 2, 3, \ldots, 800.
\] (4)

Every time the 3D scanner completes a format scan, it will return to the starting point of the scan. In the adjustment process of the laser scanner, it is found that the starting point of the \( X \) coordinate of the laser line is on the right side, so the translation arm of the translation platform should move to the right or to the right for a certain distance, so as to complete the next 3D laser scan.

2.2. 3D Point Data Denoising. Noise in 3D point cloud data is unavoidable in the gathering of 3D point cloud data by museums owing to faulty equipment or operation. Using noisy data to model interactive virtual displays in museums, on the other hand, will result in a considerable reduction in modeling accuracy [12, 13]. As a result, correlation techniques must be used to denoise 3D point cloud data. Moving least squares (MLSs) is one of the function approaches to generate grid-free approximation in the process of grid-free data processing. It has been extensively employed in the area of point cloud data denoising and has achieved excellent application impact. As a result, this article uses MLS to denoise museum data from a 3D point cloud.

The denoising process of museum 3D point cloud data is as follows:

1. Extract the above-collected 3D point cloud data of the museum [14], and calculate the amount of point cloud data \( N \).
2. A point in the 3D point cloud data of the museum is randomly selected. On this basis, the size of its influence area needs to be calculated to determine the number of terms \( m \) of the basis function \( p_i(x) \).
3. Determine the number of neighbor points in the influence area of the point \( n \). If the number of neighbor nodes is greater than the number of basis function terms, then the distance between the point and all the neighbor points needs to be calculated [15]; otherwise, return to the previous step.
4. According to the calculation results of the distance between nodes and their nearest neighbors, the weight function of each node is calculated [16], and the expression of this function is as follows:

\[
w_i(x) = \frac{e^{-(d_i/c)^2} - e^{-(r/c)^2}}{1 - e^{-(r/c)^2}}, 0 \leq d_i \leq r.
\] (5)

Here, \( r, c, \) and \( d_i \) are real constants.
5. Build the fitting function.

Construct an initial fitting function on a local sub-domain, which is expressed as follows:

\[
f(x) = \sum_{i=1}^{m} p_i(x) a_i(x),
\] (6)

\[
= p(x) a(x).
\]
Here, $\alpha(x)$ represents the node coordinate description function, that is, the coefficient to be solved. Through the analysis of the previous formula, it can be seen that in the process of constructing the fitting function [17, 18], the most important thing is to obtain $\alpha(x)$, so the weighted discrete norm of the node needs to be defined for calculation. The specific calculation formula is as follows:

$$J = \sum_{i=1}^{n} w(x-x_i)\left[p^T(x_i)\alpha(x_i) - y_i\right]^2.$$  \hspace{1cm} (7)

Here, $y_i = y(x_i)$ represents the node value at $x = x_i$. In order to calculate the exact value of $\alpha(x)$, the minimum value of formula (3) should be taken, so take the derivative of $\alpha$. The specific derivative process is as follows:

$$\frac{\partial J}{\partial \alpha} = A(x)\alpha(x) - B(x)y,$$  \hspace{1cm} (8)

$$= 0.$$  \hspace{1cm} (9)

So the following formula holds:

$$\alpha(x) = A(x)^{-1}B(x)y.$$  \hspace{1cm} (10)

where $A(x)$ and $B(x)$ represent different node matrices [19, 20], whose calculation formula is as follows:

$$A(x) = \sum_{i=1}^{n} w(x-x_i)p(x_i)p^T(x_i),$$

$$B(x) = [w(x-x_1)p(x_1), w(x-x_2)p(x_2), \ldots, w(x-x_n)p(x_n)].$$  \hspace{1cm} (11)

By substituting formula (6) into formula (9), a new fitting function can be obtained, which is described as follows:

$$f(x) = \sum_{i=1}^{n} \Phi_i(x)y_i,$$  \hspace{1cm} (12)

$$= \Phi^k(x)y.$$  \hspace{1cm} (13)

Here, $k$ represents the number of basis functions and $\Phi^k(x)$ is the shape function, which is described as follows:

$$\Phi^k(x) = \left[\Phi_1^k(x), \Phi_2^k(x), \ldots, \Phi_n^k(x)\right],$$

$$= p^T(x)A(x)^{-1}B(x).$$  \hspace{1cm} (14)

Recalculate the coordinate values of nodes according to the fitting function, and update the node coordinates according to the calculated results.

(7) Repeat steps (2)~(6) until all points are finished and the denoising results of 3D point cloud data are output;
solve this problem, this paper introduces the M-estimator, which is described as follows:

\[
\rho(e_i^2) = \begin{cases} 
0, & e_i^2 < t^2, \\
\alpha e_i^2, & e_i^2 \geq t^2. 
\end{cases}
\]  

(16)

The cost function can be expressed by the following formula:

\[
J = \frac{\sum_{i=1}^{N} \rho(e_i^2)}{\sum_{j=1}^{N} y_j} 
\]  

(17)

Here, \( y_j \) represents the cost factor.

2.3.5. Iteration Termination Judgment. Firstly, judge whether the number of interior points \( N_k \) is equal to the number of corresponding points \( N \). If so, it indicates that all corresponding points are judged to be interior points, which is the maximum consistent set. Iteration is terminated, and registration is completed. Otherwise, continue to judge whether the number of iterations \( k \) is less than \( K_{\text{min}} \) or greater than \( K_{\text{max}} \). If so, add one and return step (3); otherwise, terminate the iteration.

2.3.6. Point Cloud Registration. Point cloud registration is completed by rotating point clouds \( P \) and \( Q \) by using the optimal model parameters \( R_{pk} \) and \( R_{qk} \).

\[
\begin{align*}
\hat{p}_i &= R_{pk}(p_i - o_k) + o_1 + J, \\
\hat{q}_i &= R_{qk}(q_i - o_k) + o_2 + J.
\end{align*}
\]  

(18)

2.3.7. Building the User Experience Model. The response of people when they use or anticipate to utilise a given sort of product or service is referred to as user experience. It is also a subjective experience that people get after becoming acquainted with a product, which may manifest itself in a number of emotions. The user experience is influenced by a variety of aspects, including ease of use, functionality, and content. Through preliminary study, this article gathers the findings of competing product analyses and user surveys and creates a user psychology model based on the relevant data. A mental model is a tool in human-computer interaction that allows users to describe the presence, explain the function, and anticipate the future state of a system with a high-level perspective.

The user experience model is described as follows:

\[
W_{\text{pro}} = \omega P_w + (1 - \omega)V_w
\]  

(19)

Here, \( \omega \) represents the user weight factor, \( V_w \) represents the user experience parameter of the model, and \( P_w \) represents the user’s rating of the competing product.

2.3.8. Construction of the Museum Interactive Virtual Display Model. According to the registration results of 3D point cloud data of the museum, the interactive virtual display model of the museum was initially constructed and

| Table 2: Experimental environment. |
|-----------------------------------|
| Project                          | Parameter               |
| Computer version and model       | ASUS X550               |
| Image net dataset version        | 3.0.3                   |
| CPU                              | Intel i7-9700K         |
| Memory                           | 1 GB                    |
| Operating system                 | Windows10               |
| Hard disk capacity               | 120 GB                  |
| Data sampling frequency          | Collect data every 2 seconds |
| Simulation software              | Matlab 7.2              |

the user experience model was used to adjust the parameters of the interactive virtual display model of the museum; then, the final modeling results of the interactive virtual display of the museum were obtained:

\[
C = \frac{\alpha C_{\text{mod}} + \beta R + \gamma C_{\text{tat}}}{W_{\text{pro}}}
\]  

(20)

Here, \( \alpha \) and \( \beta \) represent a constant, \( C_{\text{mod}} \) represents the parameter adjustment range, and \( C_{\text{tat}} \) represents the basic parameters of the model.

3. Simulation Experiment Design and Result Analysis

In order to test the practical application effect of the modeling of museum interactive virtual display based on user experience is designed in this paper, it is necessary to conduct a simulation experiment design, and the specific experimental scheme is as follows:

(1) In order to ensure that the experimental results are closer to the facts, it is necessary to focus on the design of the simulation experiment environment. After analysis and comparison, this paper carries out tests in the experimental environment shown in Table 2.

(2) During the experiment, a large museum was taken as the research object, the design and construction data of the museum were collected, and the design data were revised according to the actual construction situation. The revised data were taken as the experimental sample data, so as to improve the authenticity and reliability of the simulation experiment.

(3) The method in [3], the method in [4], and user experience-based interactive virtual display modeling method of museums proposed in this paper are used as experimental methods to test the application effects of different methods by comparing different experimental indicators.

Clarity: the clarity of the museum’s interactive virtual display is a key indication for determining the modeling approach used in the interactive virtual display. As a result, the greater the picture quality, the better the museum’s interactive virtual display will be and the higher the practical application value will be.
User happiness is one of the most essential markers for determining the impact of interactive virtual museum displays; thus, the user satisfaction in various ways is compared. A total of 1000 people were chosen to take part in this experiment, and all three approaches were used on the same museum. The volunteers were asked to assess their pleasure with the museum’s interactive virtual exhibit, with 10 being the greatest and 0 being the lowest satisfaction score. On average, 1000 participants’ scores were sorted into ten categories. The satisfaction score of each group was calculated using the average score of each group.

Interactive response time: the interactive response time in the process of museum interactive virtual exhibition is an important indicator to verify the speed of museum interactive virtual exhibition. Therefore, the interactive response time of different methods is compared. The shorter the interactive response time is, the higher the speed of museum interactive virtual exhibition is and the better the practical application effect is.

3.1. Definition Comparison. According to the above-mentioned experimental design description, the clarity of the method in [3], the method in [4], and the modeling method based on user experience proposed in this paper are first compared, and the comparison results are shown in Figure 2.

By analyzing the results in Figure 2, it can be seen that the museum interactive virtual display of the method in [3] has a lower definition, the details cannot be better presented in front of users and the practical application effect is not good. Compared with the methods in [3] and [4], the modeling method based on user experience has a higher definition of museum interactive virtual display, can well present the details of exhibits in front of users, and has a good effect on Museum interactive virtual display.

3.2. Comparison of User Satisfaction. On the basis of the above experiments, user satisfaction of different methods is compared according to the experimental scheme design, and the comparison results are shown in Table 3.

By analyzing the data in Table 3, it can be seen that the average user satisfaction of the method in [3] is 6.69, the average user satisfaction of the method in [4] is 5.72, and the average user satisfaction of modeling method based on user experience is 9.45. Compared with the methods in [3] and [4], the user satisfaction of this method is higher. Therefore, it also proves that the museum interactive virtual display effect of this method is better.

3.3. Comparison of Interaction Response Time. Finally, the museum interaction response times of different methods are compared, and the comparison results are shown in Figure 3.

The interactive response time of the method in [3] ranges from 1.1 s to 1.8 s, while the interactive response time of the method in [4] varies from 1.1 s to 2.0 s, which is the longest among the three ways, according to the data in Figure 3. The interactive response time of the user experience based
modeling technique is always shorter than 0.4 s when compared to these two methods. This demonstrates that this way of museum interactive virtual display has a high speed and a practical application value.

4. Conclusions

With the rapid development of the social economy, the level of science and technology has also been improved. Therefore, virtual reality technology has been widely used in practice. This technology is a new practical technology developed in the 20th century. It has been continuously developed and improved in practical application. Therefore, it has gradually developed and advanced at this stage. The combination of virtual reality technology and museum interactive display forms a new museum interactive virtual display method, which can improve the efficiency of museum interactive virtual display and give users a better user experience. However, the traditional museum interactive virtual display modeling method has poor clarity. Because of the defects of low user satisfaction and long interactive response time, this paper proposes a museum interactive virtual display modeling method based on user experience and tests the effectiveness of this method through experiments. There are also some deficiencies in this paper, that is, there are few research examples. In the future, the research scope will be expanded, and this method will be applied to museums with different methods, so as to further clarify the practical application effect of this method and optimise this method according to the actual situation, in order to promote the further development of the field of the interactive virtual exhibition in museums.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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