Research on Museum Display Design Based on Immersive Virtual Reality Technology

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ABSTRACT. Immersive "is a term derived from the development of the internet in the new era, meaning to make people focus on the current goal (created by designers) and feel happy and satisfied, while forgetting the real world situation. Immersive virtual reality technology, on the other hand, involves the deep development of virtual technology, allowing the viewer's various senses to intuitively experience the experiences brought by the content. Therefore, the research on museum display design based on immersive virtual reality technology aims to improve the intelligent construction of museums, strengthen the cultural inheritance and study role of museums, enhance the social value and role of museums, and integrate modern technology into cultural development. By using literature review methods, the theoretical basis required for this study is organized, as well as the design direction for applying virtual reality technology to museum displays. Designing museum display content using virtual reality technology can effectively improve the presentation effect of museum display content, enhance the tourist experience of museum visitors, provide opportunities for dynamic presentation of static displays, and highlight the potential cultural value of museum displays. The research on museum display design based on immersive virtual reality technology has a strong promoting effect on the development of human society and culture, especially in cultural inheritance and study. It can enable experienced individuals immersed in virtual reality technology to deeply experience the stories behind exhibition items, as well as inherit cultural values and national spirit.

Keywords: Immersive; Virtual reality technology; Museums; Display Design

1 Introduction

At present, virtual reality technology is widely applied in fields such as education, design, and entertainment, enabling users to receive immersive experience services and meet their spiritual needs, such as cultivating and experiencing a sense of technology in education, watching 360 °design effects in design, and experiencing roller coasters in entertainment. Therefore, it is very appropriate to apply immersive virtual reality technology to them. Museum display design should not only reflect diversity, but also have a certain degree of modernization, and design a museum display centered on the

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audience where technology and culture coexist, learning and experience are shared [1]. however, the application of immersive virtual reality technology in museum display design is currently in its early stages. How to better integrate this technology with museum display design has become a topic that requires in-depth research.

Therefore, this article first outlines the importance of museum display design based on immersive virtual reality technology, which elaborates on the current status, advantages, and existing problems of immersive virtual reality and its application in museums; Secondly, analyze the principles of museum display design using immersive virtual reality technology, highlighting the direction of this technology in museum display design; Finally, the application of immersive virtual reality technology in museum display design is introduced to complete this study.

2 The Importance of Museum Display Design Based on Immersive Virtual Reality Technology

2.1 Immersive Virtual Reality and Its Application Status in Museums

Virtual reality technology is an interactive simulation technology based on computer technology that utilizes computers to generate corresponding images, sound effects, and other sensory experiences brought by the images from the perspectives of viewing, listening, and touching, forming an immersive experience[2]. The characteristics of this technology are immersion, interactivity, and conceptualization, collectively referred to as 3I, as shown in Figure 1. The immersive and prominent environment brings a sense of realism to people; Interactivity reflects the real-time and natural nature of the environment towards humans, highlighting the characteristic of letting nature take its course; Imagination emphasizes that the constructed virtual world is a very reasonable world, and all rules in the world have strong logic and specificity. In addition, according to the application of virtual reality technology, it can be classified into three technologies: virtual reality, reality augmentation, and reality mixing [3]. The mutual development of these three technologies has comprehensively applied corresponding modeling techniques, and fundamentally, they all have strong 3I characteristics; The classification criteria and angles are in three-dimensional space.

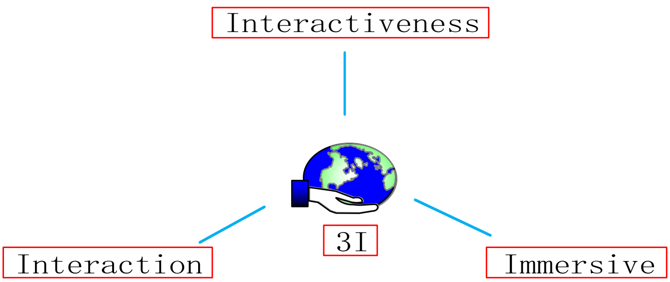

Fig. 1. Characteristics of Virtual Reality Technology

Characteristic: The characteristics of the application of virtual reality technology in museums are mainly reflected in four aspects. Firstly, it is active participation, requiring participants to actively participate in the museum's virtual reality technology experience activities, thereby increasing their museum viewing experience. Indirectly enhancing the entertainment value of museums[4]. Secondly, it is experiential, in order to enhance the emotional experience of the experimenter, causing the emotional value contained in the exhibits to be transmitted to the experimenter, achieving emotional communication between the two, and further enhancing the memory of the experimenter. Furthermore, for interactivity, the use of devices enhances the experience of the virtual world, increases the fun and interactivity of museum displays, subjectively enlarges the display space, causing the display information to change from fragments to stories, and improves the thinking, cognition, and understanding of the display items. Finally, it is immersive, breaking the limitations of vision and hearing, creating an immersive museum viewing environment that resonates with the emotions and thinking of the visitors, thereby changing the traditional thinking of the visitors in the museum and achieving communication and exchange between the exhibits and the visitors.

2.2 Immersive Virtual Reality and Its Application Advantages in Museums

To compensate for the lack of information in traditional displays, museums are influenced by space, and the basic information description of internal display items is relatively simple. By applying immersive virtual reality technology [5], museum displays can fully display their cultural colors in an infinite virtual space, and at the same time, they can jointly display related things to build a more comprehensive and intuitive information space.

Enriching the expression forms of exhibits, immersive virtual reality technology has no limitations in display[6]. It not only allows designers to innovate the display methods based on the display of internal cultural characteristics, but also presents them in the form of images, allowing viewers to experience the entertainment value of museum displays in a novel and interesting virtual space.

To meet the requirements of the times, immersive virtual reality technology can enable museums to display information, actively communicate and communicate with visitors in a dynamic form, and meet the needs of modern people for information resources[7]. However, due to the large investment in supporting equipment, most museums have not yet achieved comprehensive construction of immersive virtual reality technology. Building a multi sensory immersive experience, starting from the perspective of information immersion, to enhance the value and significance of museum displays; Immersion from the senses, satisfying users' dependence on modern technology and spiritual pursuit; By immersing the brain and deeply developing users' cognitive and understanding of their thinking, users can gain growth in knowledge, vision, thinking, and other aspects in the virtual world.

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3 Principles of Museum Display Design Based on Immersive Virtual Reality Technology

3.1 Principles of Communication Education

At present, the scientific teaching objectives of international science education are divided into knowledge and skills, processes and methods, emotions, attitudes, and values, while the universal scientific communication objectives and educational teaching objectives of museums correspond to the above three levels of objectives [9]. It can be determined that the various display forms of museums need to attract audiences, help them grow their knowledge during the experience display process, and construct a higher level of knowledge structure based on their own life experiences, thereby continuously improving the scientific and cultural literacy and aesthetic ability of the audience.

3.2 User centric principle

The user centered principle of museum display design using immersive virtual reality technology is to first classify users and clarify their museum display experience needs and reference purposes; Secondly, according to the user's cognitive process, design a technology experience process for museum displays [10], and flexibly apply various display methods to the user's cognitive process. For example, the basic introduction to the museum provided upon entry, the guzheng music played during the tour, and the discovery story of items broadcasted on television during the tour. Finally, based on the user's attention, we will focus on improving the museum display design of immersive virtual technology. Its projects with strong interactivity and sensory experience will continuously attract user attention, and other displays that cannot attract user attention will be integrated into it to attract user interest in other displays. In addition, there are also user behavior characteristics, emotional tendencies, and evaluation index systems that can serve as the design direction for user centered principles.

3.3 Principles of Environmental Immersion

Firstly, the emphasis is placed on highlighting the spatial and telepresence aspects of immersive virtual technology, helping users establish a good spatial perception and creating a realistic telepresence that resonates and synchronizes with their senses[11]; Secondly, natural interaction is achieved, utilizing the motion laws of the human body itself to achieve a one-to-one restoration of the movement of objects in virtual space compared to real space, such as stillness, displacement, acceleration, weightlessness, etc; Finally, it is important to fully utilize the limited space to maximize the immersive experience, so that museum displays are not limited by space and reduce user immersive experiences.

3.4 Technical principles

As a key technology, the real-time 3D graphic production technology should ensure that the real-time Refresh rate of graphics is 15 fps without reducing the image quality and complexity, and the VR device must maintain a graphics card configuration above GTX980[12]. In terms of hardware, the global VR technical standards should be followed to ensure that the Refresh rate and frame number are 90 or above. The higher the device resolution, the better. The minimum requirement is 2K.

4 The Application of Immersive Virtual Reality Technology in Museum Display Design

4.1 Active Visual Localization Technology Based on AR Toolkit

This technology is an open-source computer vision tracking C/C++algorithm library used to overlay virtual images in the real world and build a reality enhancement system [13] - [15]. This technology uses a fixed method to segment the image, which directly affects the quality of the matching results. There are various variations in the image collection of hardware device cameras and the identification images in the template library, such as size, displacement, rotation, etc., which require calculating the similarity between the two. So the image (P (x, y)) representing the same size as the template (T (x, y)) will be obtained by rotation, assuming that the template size is M × M. So the formula for similarity matching R (x, y) is expressed as:

$$R(x,y)=\frac{\sum_{x}^{M}\sum_{y}^{M}\left[P(x,y)-\overline{P}\right]\left[T(x,y)-\overline{T}\right]}{\left\{\sum_{x}^{M}\sum_{y}^{M}\left[P(x,y)-\overline{P}\right]^{2}\sum_{x}^{M}\sum_{y}^{M}\left[T(x,y)-\overline{T}\right]^{2}\right\}^{\frac{1}{2}}} \tag{1}$$

In addition, fault-tolerant technology, inertial positioning technology, Kalman filter, image processing technology, and other technologies will also be used. The formula is as follows.

Active visual positioning technology: T1, t2, and t3 are the translation quantities; P is the coordinate of the user's head in the world coordinate system

$$\begin{cases} X_{id}=(l+d)^{*}((id-1)\%row-1)+\frac{l}{2} \\ Y_{id}=(l+d)^{*}((id-1)/row-1)+\frac{l}{2} \\ Z_{id}=0 \end{cases} \tag{2}$$

$$P(x,y,z)=\begin{cases} x_p = t_1 + X_{id} \\ y_p = t_2 + Y_{id} \\ z_p = t_3 + Z_{id} \end{cases} \tag{3}$$

Fault tolerance technology: Using inertial positioning method for angle compensation correction to obtain accurate position based on visual positioning results;

Inertial positioning technology: $\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} \cos(\theta(t)) & \sin(\theta(t)) \\ -\sin(\theta(t)) & \cos(\theta(t)) \end{bmatrix} \begin{bmatrix} v_L \\ v_T \end{bmatrix}$ (4); θ The deviation angle between the world coordinate system and the robot coordinate system;

Kalman filter: $\begin{matrix} Z_{k+1} = A_k Z_k + G_k n_k \\ Y_k = C_k Z_k + w_k \end{matrix}$ (5); Yk is the measurement state matrix; Nk is the system noise; Wk is the measurement noise; Ak and Gk are system parameters;

Fixed threshold segmentation method: $O(x,y)=\begin{cases} 0 & 0 \le f(x,y) \le T \\ 255 & T < f(x,y) \le 255 \end{cases}$ (6);

Global threshold segmentation method: $\delta^2(T) = w_0 w_1 (u_0 - u_1)^2$ (7); $T^* = Arg\{\max_{0 \le T \le 250} \delta^2(T)\}$; W0 is the total pixel ratio of the image; U0 is the average grayscale; T * is the optimal threshold

4.2 Fault tolerant algorithm for inertial positioning

The original acceleration obtained through the Oculus head mounted display accelerometer requires coordinate conversion before it can be used to calculate the relative displacement of camera motion. For the coordinate transformation of acceleration, it mainly involves the calibration between the camera and the sensor, determining the attitude angle and position information between the two. As shown in Figure 2.

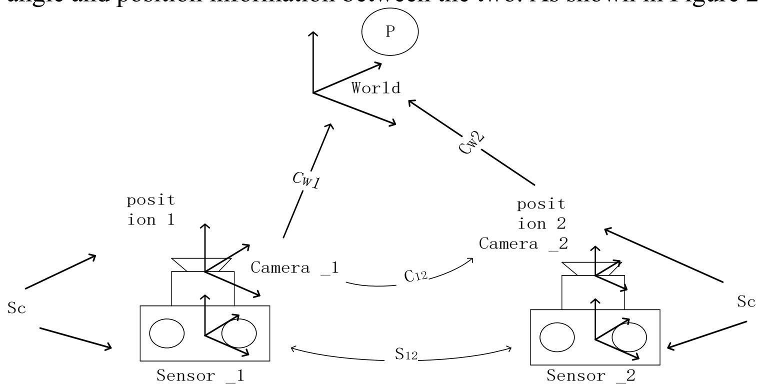

Fig. 2. Schematic diagram of coordinate transformation relationship

4.3 Experimental verification

Accuracy verification: By using intermittent occlusion markings to render visual positioning methods ineffective [16], a fault tolerant method is initiated, and the positioning results are compared with the user's actual position for error calculation; As shown in Tables 1 and 2

Table 1. Comparison of indoor positioning technologies using virtual reality technology

Technology	Infrared	Laser	Electromagnetic	Ultrasound	computer
Precision: mm	0.1~1	1~10	1~10	10~100	10~100
Range: m	1.5×1.5	4.5×4.5	r=3	r=30	unlimited
feature	Easy to interfere and block	Low investment, poor stability, and poor durability	Equipment is complex and susceptible to metal influences	Easy to be affected by temperature, significantly weakened, and with high investment	Poor stability teaching

Table 2. The X-axis positioning results and errors represented in (in millimeters)

X-axis	error	X-axis	error	X-axis	error
121.7445	1.7445	102.4528	-17.5471	109.171	-10.832
125.6537	5.6537	108.6528	-11.3471	93.9338	-26.0661
122.9884	2.9884	112.1519	-7.8480	117.2883	-2.7126
122.9884	2.9884	123.7419	3.7419	115.8991	-4.1018
144.6269	24.6269	129.4140	9.4140	115.8991	-4.1018
141.3404	21.3404	132.6526	12.6526	141.0793	21.0793

The final calculated average error value is 14.0690mm, which meets the characteristics of high visual positioning accuracy and strong robustness of inertial methods

Robustness comparison: Move in the positive X-axis direction in the real scene, walk at normal speed first, and shake when reaching a fixed position. Compare the positioning results of identification based visual positioning methods; As shown in Figure 3.

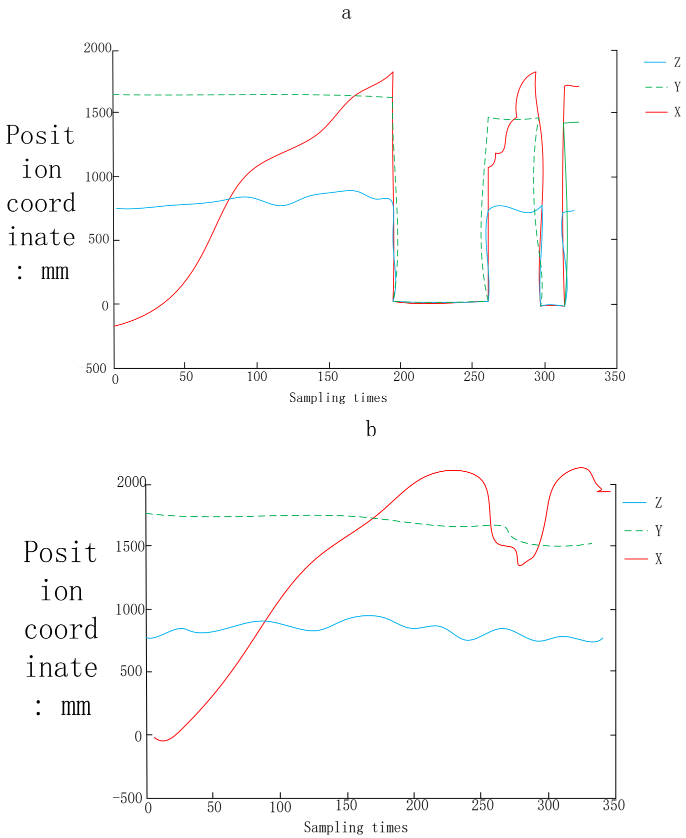

Fig. 3. Comparison of Robustness between Identification and Walking Positioning

The efficiency of walking positioning methods is higher when some users experience sudden behavior or are affected by adverse environments. However, it is not difficult to see from the figure that any noise infection, although small, cannot be ignored, and the impact of noise modification on users' virtual reality experience can be ignored.

Comparison of single frame time consumption: Three sets of experimental distances of 2.5m, 5m, and 10m were designed, using the methods proposed in this paper and the visual positioning method based on identification for positioning. The single frame refresh time during the experimental process was compared. As shown in Tables 3

Table 3. Comparison of single frame time consumption between identification positioning and walking positioning methods

Traveling distance: m Single frame duration: ms method	2.5	5	10
Identification positioning	8.332	8.475	10.053
Walking positioning	8.867	9.204	10.635

From Table 3, it can be seen that the single frame time difference between the two methods is small, so both methods can meet the requirements of immersive experience in this aspect.

5 Conclusion

In summary, the following conclusions have been drawn from this study.

The first and second parts of this study provide important theoretical support and practical basis for this study, and point out the research direction for this study;

The third part of this study focuses on the active visual positioning technology based on AR Toolkit, explaining the practical value and role of this technology. Through accuracy verification, robustness comparison, and single frame time comparison, we understand the impact of two methods, identification positioning and walking positioning, on the user's virtual world experience, and determine the reasons for affecting the user's immersive experience of the virtual world.

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