Research on the Strategy and Practical Mechanism of Museum Exhibition Space Design Based on Immersive Experience

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Abstract: With the development of science and technology, immersive experience has become an important trend in museum exhibition design. The purpose of this paper is to study the strategy and practice mechanism of museum exhibition space design based on immersive experience, to explore the impact of immersive experience on museum design and how to enhance the audience's sense of immersion through innovative design methods. The article firstly analyzes the concept of immersive experience and its application in museum design, and points out that immersive experience can enhance the exhibition effect through spatial layout, dynamic line design, multi-sensory interaction and scientific and technological means, breaking the limitations of traditional exhibition methods. This paper discusses the core strategy of museum exhibition space design, including the combination of spatial layout, dynamic line design, realization of multi-sensory experience and modern technology application. Through case studies of typical museums at home and abroad, it evaluates the practical application effects of these design strategies, and puts forward the challenges and future development direction of immersive design. The research in this paper provides theoretical guidance and practical reference for the innovation of museum exhibition design, aiming to promote the wide application and development of immersive experience in museums.

1. Introduction

As an important place for cultural dissemination and historical education, museums have faced the contradiction between traditional display methods and audience needs in recent years[1]. In the era of informationization and digitization, the audience has put forward higher requirements for the interactivity, participation and immersion of museum exhibitions[2]. Immersive experience, as an emerging exhibition method, provides a more attractive and interactive museum visiting experience through the use of advanced scientific and technological means and design concepts, enabling the audience to deeply participate in the exhibition content in their senses[3]. Immersive experience not only changes the traditional museum display, but also promotes the innovation of the concept of museum space design, and promotes the development of exhibition design in the direction of more immersion, interactivity and participation[4].

With the progress of virtual reality (VR), augmented reality (AR), holographic projection and other technologies, the application of immersive experience in museum exhibition is gradually increasing and showing a diversified development trend[5]. These emerging technologies provide more possibilities for the design of museum exhibition space, change the way of interaction between the audience and the exhibition, and at the same time put forward new challenges and opportunities for museum designers[6]. It is of great theoretical significance and practical value to study the strategy and practice mechanism of museum exhibition space design based on immersive experience, and to explore its application principle, design method and practice effect[7].

This paper will focus on the application of immersive experience in museum exhibition, analyze its impact on space design, and study how to enhance the sense of immersion and interactivity of the exhibition through reasonable design strategies and innovative technical means[8]. Through the analysis of related cases, the practical mechanism of immersive design in museums is further summarized, aiming to provide theoretical basis and practical guidance for the innovation and

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development of museum exhibition design.

2. Impact of immersive experience on museum exhibition space design

With the continuous progress of science and technology, immersive experience has gradually become an important part of museum exhibition design. The traditional museum display is mainly based on static exhibits, with low audience participation and a single exhibition form, which is difficult to stimulate the interest and curiosity of the audience. The immersive experience, however, brings the audience into a more three-dimensional and interactive exhibition environment through the sense of multi-sensory participation, breaks the boundaries of traditional exhibitions, and enhances the attractiveness and infectious force of exhibitions[9]. In this context, the design concept and method of museum exhibition space has undergone profound changes, and the introduction of immersive experience has injected new vitality into the design of exhibition space[10]. Formula for space layout optimization:

$$S = \sum_{i=1}^{n} (A_i \cdot D_i) \quad (1)$$

One of the core elements of immersive experience is the multi-dimensional construction of space. Unlike traditional museums that present exhibits through a single display form, immersive exhibitions emphasize the interactivity and flexibility of the space, so that the content of the exhibition is highly integrated with the sensory experience of the audience. The spatial layout not only considers the display of exhibits, but also needs to design a matching spatial atmosphere according to the theme of the exhibition and the experiential objectives[11]. Through the comprehensive use of lighting, sound, image, odor and other elements, an environment with a strong sense of immersion is created, so that the audience can feel an immersive experience the moment they enter the exhibition hall[12]. This kind of design not only requires the formal aesthetics of the space, but also pays more attention to the functionality of the space and the depth of the audience's experience,Space Layout and Visitor Flow,showed in Figure 1 :

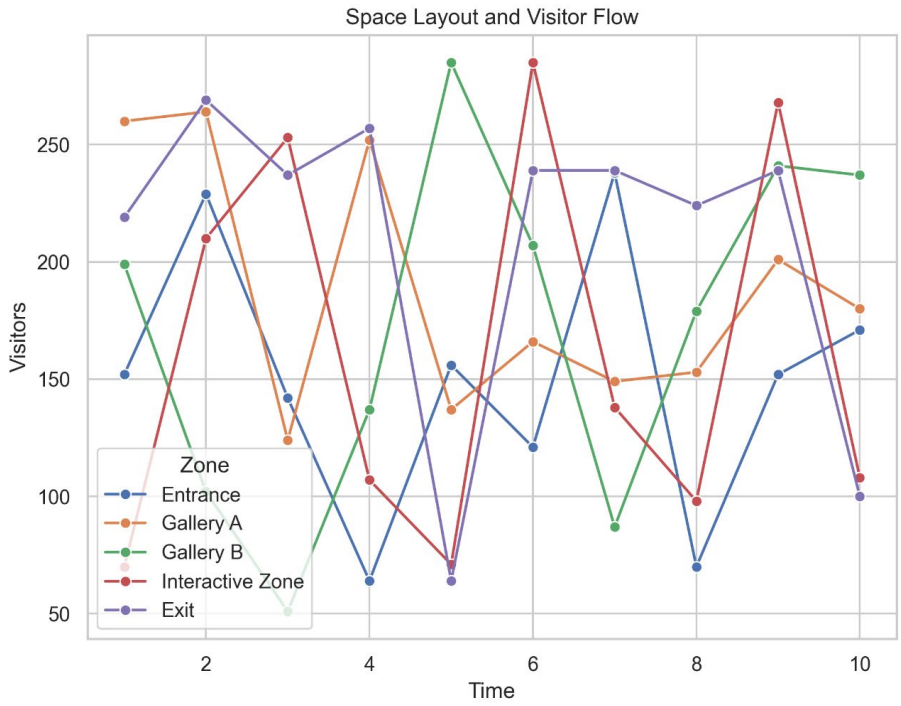

Figure 1 Space Layout and Visitor Flow

The realization of immersive experience relies on the application of multi-sensory interactive technology. Traditional museum exhibits are mostly visual, and the audience's sense of participation

is weak, while the immersive experience allows the audience to perceive the content of the exhibits in an all-round way through multi-sensory stimulation such as sound, touch, temperature and odor. Virtual Reality (VR) technology can allow the audience to enter virtual historical scenes or natural environments through simulated environments, while Augmented Reality (AR) technology is able to combine virtual elements with the real environment through cell phones or AR glasses, making the interaction between exhibits and the audience more intuitive and vivid. Haptic feedback and temperature change can also be used to increase the immersion of the exhibition and enhance the audience's sensory involvement, thus realizing a deep interactive experience. Formula for visitor flow in a museum space:

$$F = \frac{V \cdot T}{D} \quad (2)$$

In the design of museum exhibition space, immersive experience is not just a pile of technology, but more importantly, the integration of design and technology innovation. Museum designers need to comprehensively consider the combination of spatial structure, display content and technical means, so that the immersive experience can be realized efficiently. The use of technology needs to be in line with the theme and objectives of the exhibition, avoiding formalism and ensuring that the technology serves the delivery of the exhibition content. In history museums, virtual reality technology allows the audience to "experience" historical events, while in art museums, augmented reality technology allows the audience to more deeply understand the background and creative process of the artwork. This innovative spatial design not only enhances the display effect of the museum, but also strengthens the audience's sense of participation and memory, which in turn changes the visiting experience of traditional museums, Interaction Time and Engagement, showed in Figure 2:

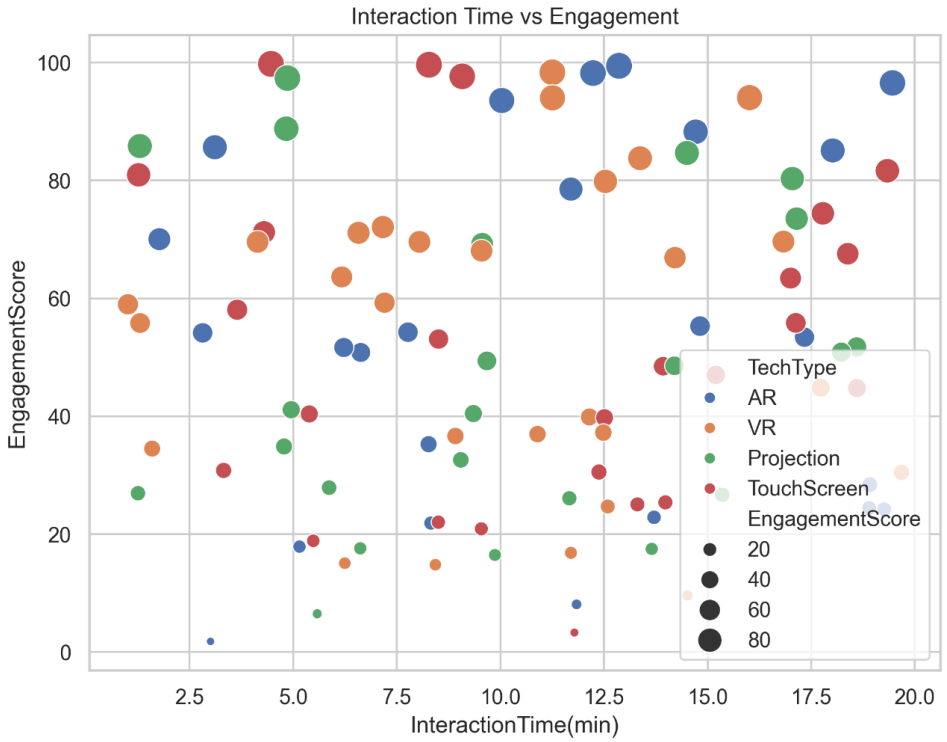

Figure 2 Interaction Time and Engagement

3. Strategy and Practice Mechanism of Museum Exhibition Space Design

The strategy and practice mechanism of museum exhibition space design involves how to create an immersive exhibition environment through reasonable space layout, dynamic line design, multi-sensory experience and modern technology application. Specifically, the spatial layout and dynamic

line design need to optimize the mobility of the exhibition space and the audience's visiting route, in order to enhance the convenience and interest of the visit; while the multi-sensory interactive experience enhances the audience's sense of immersion and interactivity by means of sound, light, shadow and tactile sensation, and improves the exhibition's participation and depth of perception; at the same time, the application of science and technology, such as virtual reality, augmented reality and other technologies, brings museums a At the same time, the application of science and technology, such as virtual reality, augmented reality and other technologies, has brought richer means of display for museums, changed the way of interaction between the audience and the exhibits, and promoted the innovation of exhibition forms. The comprehensive application of these three aspects together constitutes the core practice mechanism of immersive museum exhibition design, which helps museums to realize a more vivid, interactive and attractive display effect.

3.1 Spatial layout and dynamic line design

Space layout and dynamic line design is an important part of museum exhibition space design, which directly affects the audience's visiting experience. A good spatial layout can optimize the sequence of exhibits and the activity path of the audience, and provide a clear and smooth visiting experience for the audience. The spatial layout of the museum should be reasonably divided according to the theme of the exhibition and space conditions, taking into account the nature of the exhibits, the audience's visiting habits and the interactive needs of the exhibition. For large-scale historical exhibitions, the content of the exhibition can be organized in accordance with the timeline, theme or cultural background by way of partitioning to help the audience better understand the vein of the exhibition. For art exhibitions, independent exhibition areas can be set up to allow each piece of work to obtain sufficient display space, avoiding visual interference and a sense of oppression. Formula for interaction time in an immersive exhibit:

$$I = \sum_{j=1}^{m} \left(T_j \cdot E_j \right) \quad (3)$$

The design of the moving line is the core part of the space layout, which is related to the smoothness of the audience's visit and the sense of experience. Reasonable dynamic line design not only needs to ensure the mobility of the audience in the exhibition hall, but also to create a visit route that can stimulate the desire to explore. The design of circulation routes in museums is usually organized according to the scale and content of the exhibition, avoiding crowding and repetitive visits, but also ensuring that the audience can enjoy each exhibit in a step-by-step manner. Through the use of signage, appropriate wayfinding and stopping spaces, the design of a moving line guides the visitor to the key areas of the exhibition, while also creating appropriate stopping points where the visitor can pause to enjoy, reflect or interact with a particular area, Sensory Input and Engagement Level, showed in Figure 3:

The design of the moving line should also be combined with the design of interactive areas and rest areas in the space layout to ensure the comfort and flexibility of the visiting process. The setting of rest areas is particularly important, especially in large museums, where appropriate rest points can provide visitors with space to relax and avoid prolonged fatigue. The design of the interactive area is equally important. By setting up touch screens, virtual reality equipment or art installations, etc., it breaks the traditional one-way display mode and enhances the interaction between the audience and the exhibits. These elements not only enrich the visiting experience, but also stimulate the audience's deep thinking and participation in the exhibits. Formula for sensory engagement:

Figure 3 Sensory Input and Engagement Level

$$S_e = \sum_{k=1}^{p}(I_k \cdot W_k) \quad (4)$$

Technology Impact on Visitor Immersion, as shown in Figure 4:

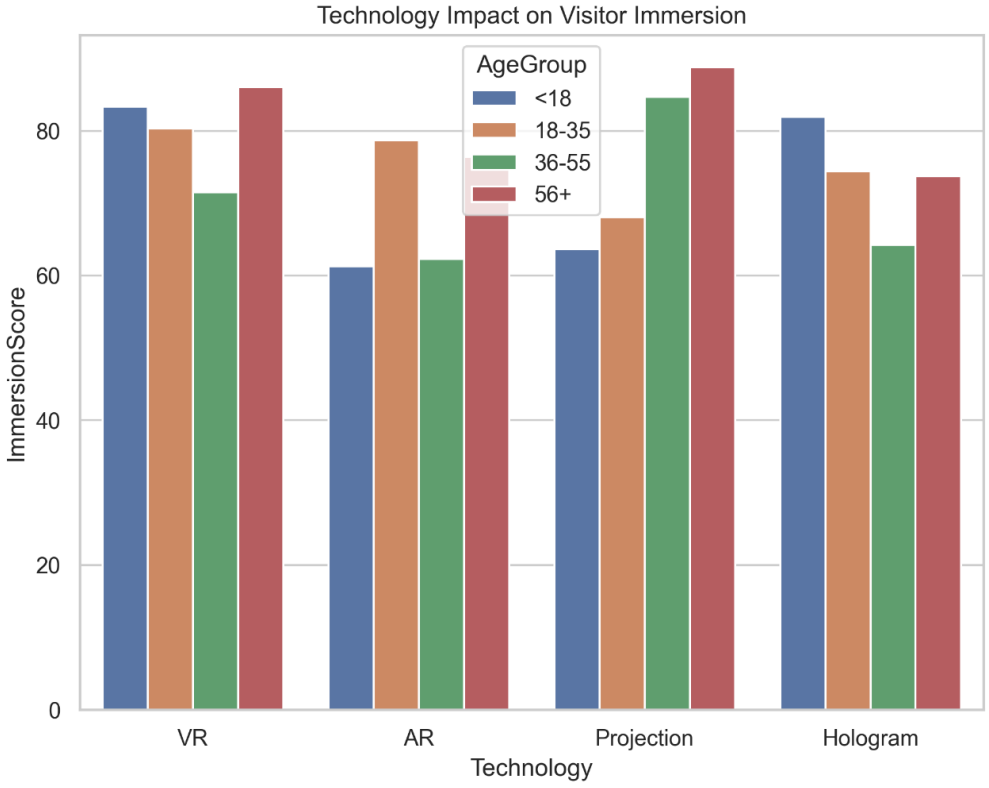

Figure 4 Technology Impact on Visitor Immersion

In the practice of space layout and dynamic line design, it is also crucial to consider the needs of different audience groups. Museum designers should adjust the dynamic line and space design according to the different characteristics of the target audience. For children or elderly audience, the design should try to take into account the barrier-free access and easy-to-understand display. For modern museums with a strong sense of technology, it may be necessary to add more innovative elements, such as movable exhibition walls and virtual interactive areas, to enhance the interactivity and diversity of the exhibition. Through reasonable dynamic line design and space layout planning, the display effect of the museum can be effectively enhanced to optimize the overall visiting experience of the audience, showed in Figure 4.

3.2 Realization of multi-sensory interactive experience

The realization of multi-sensory interactive experience is a key link in the immersive museum exhibition design, which enables the audience to interact with the exhibits in multiple dimensions through the participation of multiple senses such as visual, auditory, tactile, olfactory, and so on, so as to enhance the sense of immersion and participation in the exhibition. Visual experience is the core of multi-sensory interaction. Through well-designed exhibition lighting, video images, dynamic displays and other elements, museums are able to create layered and changing display effects. The use of projection technology can combine the exhibition space with the exhibits to create virtual historical scenes or interactive displays of artworks, so that the audience is not just an observer, but a part of the participation. The application of video mapping and holograms also gives exhibits a more vivid, three-dimensional effect, further enhancing the audience's visual experience. Formula for technology impact on visitor immersion:

$$T_i = \frac{P}{C} \quad (5)$$

In addition to vision, the use of hearing plays an equally important role in the immersive experience. Museums can enhance the atmosphere and emotional expression of the exhibition through background music, environmental sound effects, voice explanation and other sound elements. In history museums, the audience hears the audio of the historical events at that time through headphones, restoring the sound scene at that time, thus creating a stronger sense of immersion. In nature museums, sound can be used to simulate the sound of forests, oceans and other natural environments, so that the audience feels as if they are in a real natural landscape. This auditory interaction not only enhances the immersion of the situation, but also makes the content of the exhibition more vivid and helps the audience to deeply understand the stories and culture behind the exhibits, Visitor Retention Based on Interactive Features, showed in Figure 5:

The introduction of tactile experience is another important dimension in multi-sensory interactive design. Through the design of touch screens, tactile devices, and analog materials, museums are able to provide visitors with a direct tactile experience. Many museums use touch interactive screens or touch walls to enable visitors to interact directly with the exhibits to obtain more information or learn about the details of the exhibits. In some science and technology museums, visitors can feel the texture of different materials by touching tactile devices, or even experience ancient tools or animal skin by simulating tactile feedback. This tactile interaction can increase the interest and participation of the exhibition, break the traditional display mode, and allow the audience's body and senses to participate in the exhibition. Formula for visitor retention based on interactive features:

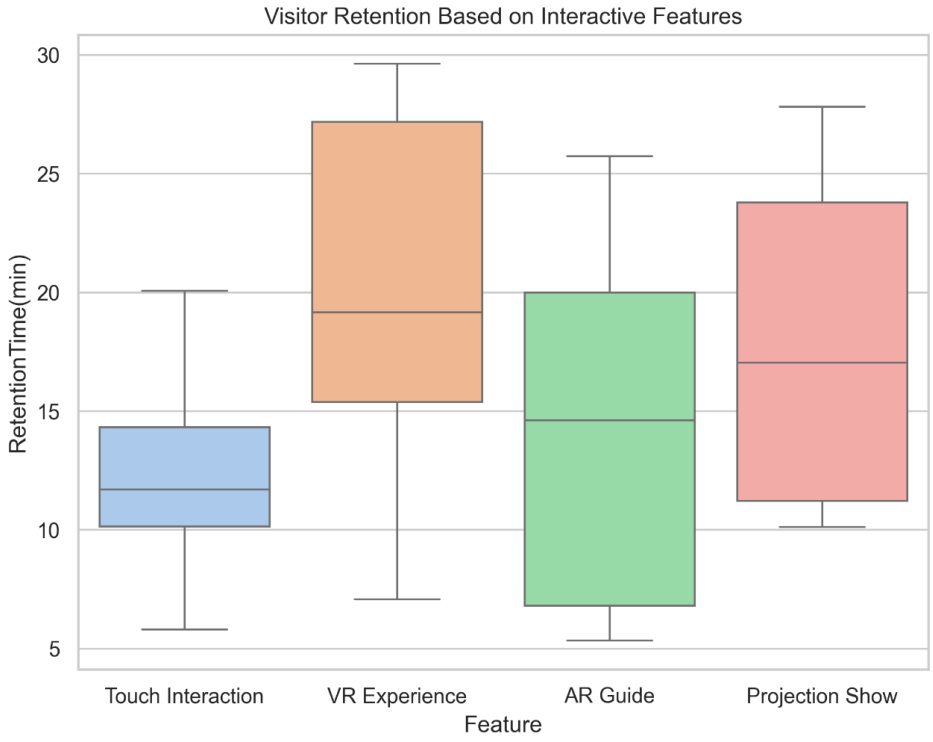

Figure 5 Visitor Retention Based on Interactive Features

$$R_v = \alpha \cdot (N \cdot I) \quad (6)$$

In multi-sensory interactive design, the sense of smell, as a more unique sense, has also been applied to exhibition design by more and more museums in recent years. Through the design of smell, museums can trigger the emotional resonance of the audience and strengthen the atmosphere of the exhibits or display scenes. When displaying exhibitions on natural ecology or historical and cultural themes, by playing the odors of specific environments, such as forests, flowers, and the aroma of ancient crafts, etc., they can let the audience feel the historical or cultural background related to the exhibits in their sense of smell, thus enhancing their perception of the content of the exhibition. Although the application of olfactory technology is still in the exploratory stage, it has a non-negligible potential to enhance immersion and emotional connection, and has great application prospects especially in creating unique experiences and reinforcing certain display emotions.

3.3 Technology Application and Innovative Design

Technology application and innovative design play a crucial role in modern museum exhibition space, especially in the realization of immersive experience, the introduction of technological means has greatly enriched the expression of the exhibition. Virtual reality (VR) and augmented reality (AR) are the most widely used technological means in the current museum exhibition design. Virtual reality technology can create an immersive virtual environment, allowing the audience to "personally" enter the historical events or the creative scene of the work of art, as if traveling through time and space, immersive experience of the story behind the exhibits. Augmented reality technology combines virtual elements with realistic scenes to give viewers a more interactive experience in the physical environment. When viewers scan the exhibits through their cell phones or AR glasses, virtual historical figures, plants and animals, or information will be presented in front of their eyes in real time, enhancing the interactivity and interest of the display. These technologies have enabled museums to move away from the traditional display mode to a more vivid, interactive and personalized visitor experience.

In addition to VR and AR technologies, projection technology is also an important innovation in museum exhibitions. Projection mapping technology is capable of projecting two- or three-

dimensional visuals onto irregular surfaces, creating stunning dynamic displays. Museums can utilize this technology to perfectly combine historical scenes, cultural heritage, art works and other contents with the pavilion space, presenting a brand new visual experience. In some art exhibitions, projection mapping can zoom in or change the details of a painting to show the process of creating the painting, or even let the characters in the painting "walk out" to interact with the audience. In nature museums, projection technology can make sleeping dinosaurs come back to life, and even simulate natural disaster scenes, so that the audience feel an immersive visual impact. These innovative display methods not only enhance the attractiveness of the exhibition, but also break the singularity of the traditional display, making the exhibition space become more dynamic and diverse.

The application of modern technology is not only limited to visual and spatial presentation, but also can greatly enhance the interactivity and participation of the museum. Touch screen, sensor, sound control system and other technical means can allow the audience to interact with the exhibits in real time, get more information or participate in the activities therein. In some science and technology museums, touch interactive screens and tactile sensing devices enable visitors to directly manipulate the content of the exhibits, thus deepening their understanding of and interest in scientific principles, historical events or works of art. The application of voice recognition technology also provides museums with new ways of interaction, allowing visitors to interact with exhibits by voice, obtain detailed background information or participate in puzzle solving games. Through these technological applications, museums are not only able to enhance audience participation, but also provide a personalized visiting experience according to the interests and needs of the audience, making the content of the exhibition more educational and entertaining.

The application of innovative design in museums is not only pure technology stacking, the key is how to closely integrate these technological means with the exhibition theme, space layout and audience experience needs. A successful application of science and technology often requires designers to start from the audience's point of view, and comprehensively consider the delivery and experience effect of the display content. When displaying cultural heritage, virtual reality technology is not only to present the face of ancient civilization, but also to allow the audience to participate in the reproduction of ancient life scenes through interactive design, increasing their historical perception; in art exhibitions, augmented reality technology, in addition to displaying the backstory of the art works, also allows the audience to participate in them through their own creations, providing an innovative mode of interaction. The key to innovative design is how to integrate the technology between the display content and audience interaction, so that the technology is not only an auxiliary tool, but also a part of the exhibition, to enhance the overall sense of immersion and interactivity, and to create a brand new museum visit experience.

4. Practical cases and analysis of immersive museum exhibition design

Practical cases of immersive museum exhibition design have been gradually developed around the world, and many museums have created a more profound and multi-dimensional experience for the audience through the introduction of innovative design concepts and technological means. Take the Dutch Vermeer Centrum in Amsterdam as an example, the museum closely integrates the works of the 18th century Dutch painter Vermeer with the historical background through immersive exhibition technology. Using Virtual Reality (VR) and Augmented Reality (AR) technologies, the museum allows visitors to "step into" Vermeer's paintings, experience the scene, and gain insight into the historical context behind the paintings. Through holograms, the museum no longer limits itself to static displays of Vermeer's works, but provides the audience with an immersive art experience, demonstrating the great potential of immersive design in art museums.

Another noteworthy case is the "Dinosaur Resurrection" exhibition at the Natural History Museum in Los Angeles, USA. By utilizing projection mapping technology and interactive touch screen, the exhibition takes the audience back to the ancient times and brings dinosaurs back to life in the exhibition space. Through projection technology, the museum is able to not only show the form of dinosaurs, but also simulate their living environment and ecosystem. By touching the interactive screen, the audience can explore the different species, habitats and ways of survival of dinosaurs, and even

experience the interactive situation of dinosaurs in specific environments. The museum also recreates the natural environment of the dinosaur era through sound and odor simulations, enhancing the sense of immersion and making the audience feel as if they were in an ancient world. This case demonstrates the application of immersive experiences in nature museums, which not only enhances the educational aspect, but also increases the entertainment and fun of the visit.

The Museum of the Future in Berlin, Germany, realizes the ultimate application of immersive experience in the display of technology and future themes. Through highly integrated virtual reality (VR) technology and holographic projections, the museum transports visitors to multiple perspectives of the future world. The exhibits include cutting-edge technologies such as artificial intelligence, space exploration, and robotics. Visitors can not only experience future scenarios such as smart cities and space travel through virtual reality, but also interact with the exhibits through augmented reality to get personalized information. The design of the museum not only focuses on the innovation of visual and auditory experience, but also incorporates haptic interaction, which allows the audience to directly participate in the exploration of future technology through touch-sensitive technology. This case highlights the important role of technological innovation and immersive design in the museum of the future, as the audience flows between the virtual world and the real world, gaining an unprecedented futuristic experience.

The Shanghai Museum of Nature in Shanghai, China is an example of a museum that incorporates a large number of immersive and interactive elements in its exhibition design. The museum creates a highly immersive natural environment by combining sound, light, electricity, gas and other technologies. In the Dinosaur Pavilion area, visitors touch different dinosaur models through a sensor device, and the system automatically plays related sound effects and historical information, and even sometimes simulates the living conditions of dinosaurs in their habitats. The underwater world area of the museum, on the other hand, through panoramic projection and tactile interactive devices, allows the audience to feel as if they were in the deep sea and experience the diversity of the underwater world. Each exhibit area uses different immersive technologies to enhance the interactivity between the audience and the exhibits, ensuring that visitors are not only recipients of knowledge, but also participants in the exploration. The skillful use of these technologies makes the exhibition content of the Shanghai Nature Museum educational as well as entertaining and interactive, attracting a large number of family visitors and young tourists.

5. Conclusion

Immersive experience, as an innovative direction of museum exhibition design, is constantly changing the traditional museum display mode and audience experience. Through the introduction of multi-sensory interactive technology, immersive design breaks the distance between the audience and the exhibits, enabling the audience to participate and perceive the exhibition content more deeply. The spatial layout, dynamic design and skillful application of technology not only enhance the attractiveness of the exhibition, but also strengthen the educational function and cultural dissemination effect of the exhibition. As a carrier of culture and history, the introduction of immersive experience can not only enhance the audience's interest and participation, but also provide a more vivid and expressive means of display for museum exhibitions.

However, immersive museum exhibition design still faces some challenges, including the complexity of technical realization, cost issues and the diversity of audience needs. Museum designers need to continue to innovate and explore, closely integrating modern technology with the museum's cultural mission to ensure that the use of technology enhances immersion while maintaining the rigor and depth of the cultural display. With the further development of science and technology, immersive experience is expected to be more widely used in museum design, promoting the design of museum space to a more diversified, interactive and personalized direction.

Museum exhibition design based on immersive experience is not only a revolution of exhibition form, but also provides new possibilities for the development of museums. Through reasonable design strategies and practice mechanisms, immersive experience is expected to become an important part of future museum design, which not only enriches the cultural experience of the audience, but also brings

new enhancement to the educational function and social value of museums.

References

[1] Liu Y, Yan Z, Ni Y, et al. A study on mechanism of voltage collapse based on the theory of transversality of equilibrium points[J]. Electric Power Systems Research, 2004, 70(2):163-171. DOI: 10. 1016/j.epsr.2003.12.004.

[2] Ferreira M P , Mello D C D ,José Pinto Duarte.The Grammar of Movement: A Step Towards a Corporeal Architecture[J].Nexus Network Journal, 2011, 13(1):131-149.DOI:10.1007/s00004-011-0058-4.

[3] Li S , Zhang H , Zhou M .Pseudo-global strategy-based visual comfort assessment considering attention mechanism[J].Multimedia Systems, 2024, 30(6):1-12.DOI:10.1007/s00530-024-01570-y.

[4] Griffin K W , Botvin G J , Williams C ,et al.Using virtual reality technology to prevent substance misuse and violence among university students: A pilot and feasibility study:[J].Health Informatics Journal, 2024, 30(4):443-448.DOI:10.1177/14604582241290712.

[5] Saghiri M A , Vakhnovetsky J , Nadershahi N .Scoping review of artificial intelligence and immersive digital tools in dental education[J].Journal of dental education, 2022, 86(6):736-750. DOI: 10. 1002/jdd.12856.

[6] Gao Z , Wang H , Feng G L H .Exploring Sonification Mapping Strategies for Spatial Auditory Guidance in Immersive Virtual Environments[J].ACM transactions on applied perception, 2022, 19(3):1-21.DOI:10.1145/3528171.

[7] Hermas A A , Morad M S .A comparative study on the corrosion behaviour of 304 austenitic stainless steel in sulfamic and sulfuric acid solutions[J].Corrosion science, 2008, 50(9):2710-2717. DOI: 10.1016/j.corsci.2008.06.029.

[8] Basu T , Bannova O , Camba J D .Mixed reality architecture in space habitats[J].Acta Astronautica, 2021, 178(152):548-555.DOI:10.1016/j.actaastro.2020.09.036.

[9] Rojas F , Tarnogol F , Yang H S .Dynamic social formations of pedestrian groups navigating and using public transportation in a virtual city[J].The Visual Computer, 2016, 32(3):335-345. DOI: 10. 1007/s00371-015-1187-7.

[10] A G L, B J P, Asuncion Lledó c. Inclusion of immersive virtual learning environments and visual control systems to support the learning of students with Asperger syndrome[J].Computers & Education, 2013, 62(1):88-101.DOI:10.1016/j.compedu.2012.10.028.

[11] Peter, McLeod, and et al. How soccer players head the ball: A test of optic acceleration cancellation theory with virtual reality [J].Vision Research, 2008, 48(13):1479-1487. DOI: 10. 1016/j. visres. 2008.03.016.

[12] Guo P, Su W, Zhang X, et al. Modeling the non-uniform retinal perception for viewport-dependent streaming of immersive video[J]. Multimedia Systems, 2024, 30(4): 1-16. DOI: 10. 1007/s00530-024-01434-5.