Digital Twin for Immersive Exhibition Space Design

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Abstract

This research aimed to find an efficient method of responding to the various variables that may arise during the process of designing and constructing an immersive exhibition space. A digital twin of the exhibition space was generated, a real-time rendering method was applied using a game engine, and the optical phenomena of several typical devices used in immersive exhibitions were simulated. The functions simulated in this study are applicable to the generated digital twin to predict how the various devices installed in the exhibition space would operate in the actual exhibition. Thereby, the possibility that the simulation results of the core elements that constitute the exhibition content be immediately applied to the operation of the various devices in the exhibition space in real-time could be explored. Not all the devices and functions used in an immersive exhibition were simulated, so the model used in the paper must be modified according to the circumstances of the applications. Through additional research, the method of responding to various installations and devices must be expanded.

Keywords

Digital Twin, Game Engine, Immersive Exhibition, Pre-visualization, Virtual Environment.

Introduction

The growing demand for advanced cultural lifestyles and the development of digital media have brought major alterations in the presentation of exhibition spaces, and the accelerating social, cultural, and economic reforms and digital transformation caused by the unprecedented global pandemic have increased the importance of developing and utilizing digital twin technologies. The digital twin platform, with great shared value as a public good, can be the core solution for the cultural and performance content sectors in coping with the economic and industrial transformations caused by the pandemic. There is a high utilization value of the exhibition virtualization model through the digital twin platform as an open platform for virtually-fused economic activities where business entities in various cultural and performance content fields can create new added value (Chung, 2021).

In contrast to conventional object-focused exhibitions, immersive exhibitions use technology as a medium to systematically connect the components to form the exhibition object. The main components used in immersive exhibitions are lights, beam projectors, lasers, sensors, fog machines, sculptures, etc., and the inevitable consideration in the process of installing them in confined spaces is reducing unnecessary interferences of each element. The general trial and error experienced during the process of constructing an immersive exhibition usually arise from the failure of predicting the interferences between the components and the secondary effects of the installed equipment, which could be seen as transitional characteristics. Therefore, improving the accessibility and compatibility of the performance production systems that can provide a single integrated platform from the spatial works such as stage equipment and lighting for previsualization to the simulation is necessary. Moreover, it is necessary to develop an online-based integrated performance production system, that can simulate without being limited spatial and temporal constraints (Song et al., 2020).

This research aimed to establish a method of responding in advance to various variables that might occur during the design and construction processes in an immersive exhibition space. To achieve this, a digital twin of the immersive exhibition space was generated, a real-time rendering method was applied using the generated model and a game engine, and several typical optical phenomena used in immersive exhibitions were simulated.

Digital twin

The digital twin is a variety of cyber-physical systems that combine the real world, which is the physical environment, and the virtual world, which is the digital environment, supported by the development of hyper-connectivity, superfusion, and superintelligence technologies. The digital twin could be considered as the total assembly of digital technologies including 5G technology, artificial intelligence, machine learning, etc., and it provides derived values from realizing completely identical actual objects, systems and environments in a virtual digital space.

When simulating the digital twin, what must universally come to mind is a 3D image. Until now, 3D models have been mainly used in some special industries. As 3D technology applications began to expand to various other industries, they began to be utilized in the visualization domain of game engines considering the size and performance of 3D models. However, generating a 3D model is not in itself the simulation of a digital twin. The 3D model is merely one method of imitating and representing real-world objects, and it is only when the attributes of the objects are expressed in the virtual world that the foundation for a digital twin is built, which is only why a 3D model is used. Deloitte (2018) described that the digital twin operates in a structure of generation, transmission, synthesis, and analysis. Data is generated through various sensor collection technologies and simulated in 3D. It is then communicated through communication interfaces such as 5G, and numerous technologies are demanded from the integrated control and analysis by artificial intelligence and machine learning through data processing in the digital twin to visualization processes. Therefore, the digital twin as a collection of automation tools in the virtual space equal to the real world can be considered as one hyper-automation system. Sustained development is only possible when the advancements in the physical environment such as real-world sensors, simulation technologies, simulation, and the digital environment such as prediction technologies are achieved. Thus, the digital twin digitally stores all product records and manages the overall flow, which contributes to industrial development through real-time feedback. Insights unobtainable in the past can be provided by identifying the circumstances in which the issues occur (Aaron & W. Lane, 2020).

Immersive exhibition

Figure 1 shows an example of an immersive exhibition. An immersive exhibition attempts to deliver synthetic immersion and novel experiences to audiences by projecting into space with numerous devices the signals reinterpreted through multimedia to reconstruct the original work with technology as a medium. The elements constituting the exhibition connected through technology have a cyclic structure and convey intensified and expanded experiences to all five senses of the audiences (Lee et al., 2021). Unlike conventional exhibitions solely reliant on the visual recognition function, immersive exhibitions are characterized by the audiences' experiences of becoming one with the artwork based on a given worldview, actual imitations, and image-forming metaphors, by freely roaming around the exhibition area(Bae & Song, 2016).

Figure 1. Example of immersive exhibition

Previsualization

Previsualization refers to the minimization process of the trial and error that occur during the actual production stage by using computers to simulate imagined images(Previz, Dictionary of IT, 2021). The miniatures or mockups can also be seen as a sort of previsualization, rather than a new term or special work. Thus, any work using any tool can be categorized as previsualization, if it is a process of exploring various possibilities, anticipating problems, and solving them in advance, before the production period in which a significant amount of time and costs are invested. The film industry, representing the visual image industry, is the oldest industrial sector that utilized pictorial storyboard type previsualization since the beginning of the 20th century. Owing to the recent development in computer graphics technology, it tends to be produced as 3D animation.

Exhibition space previsualization using game engine

The characteristics of multimedia that constitute immersive exhibitions challenge the design of the exhibition space and create a spatial atmosphere that is incomprehensible through general design alone. Gernot Böhme stated, "the fundamental phenomenon of perception is the atmospheric perception of presence," and the atmosphere is at the root of this. Böhme divides atmospheric perception into two categories: the atmosphere which is the relational state felt by the subject while receiving an emotional response from the object, and the atmospheric which is the attribute of the object possessed by the subject. The atmospheric, according to Böhme, is each space having its own mood and the mood not residing inside the spectator but in his outsider space, which is filled with his particular personality (Böhme, 2001).

Sensibility is the outcome of the ability to accept changes in the surrounding environment, grasp their meaning, and perceive them, and the effect of the brain's relevant memory functioning. The sensibility function varies according to the individual's knowledge, experience, state of the mind and body, and surrounding environment. In consideration of the fact that the individual sensibilities to the same sensory stimulus may manifest differentially depending on the state of the individual mind and body is under and the surrounding environment, it is comprehensible that the atmosphere experiences and receives human sensibility to form an emotional relationship with the space (Lee, 1998).

The interactional properties of game engines can be one methodology to address these issues. A game engine is a development tool that includes real-time graphic rendering functions such as computer games and interactive authoring modules. Games engines are used in various fields due to their flexible applicability(Kim & Chai, 2020). In this work, the basic avatar provided by the game engine was assumed as the audience to construct the exhibition space.

1. Exhibition space

There are two methods of producing exhibition spaces for digital twins: the blueprint-based modeling method and the 3D scan data-based space generation method. In the case of the blueprint-based modeling method, the exhibition space can be generated with given numerical values and forms. However, the data generated by 3D scanning has irregular mesh structures, which requires a retopology process for the application in interactive contents. As shown in Figure 2, the two methods were combined in this study.

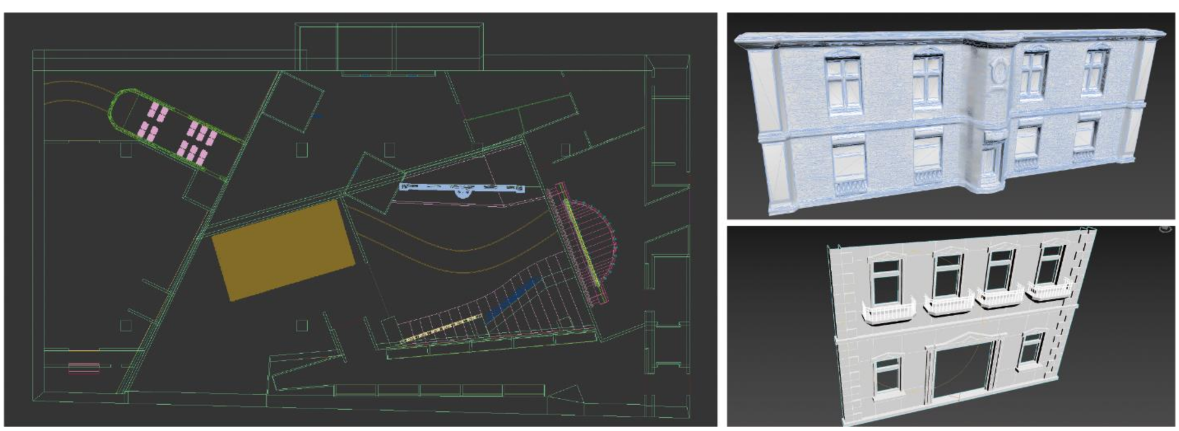

Figure 2. Blueprint-based modeling and retopology process

2. Illumination visualization

Figure 1 presents the process of ascertaining the location and intensity of lighting used in space through visualized illuminance. The Illuminating Engineering Society (IES) photometric files provided by lighting manufacturers can be applied to ascertain accurate lighting patterns, supporting designers to stage the space as they intend.

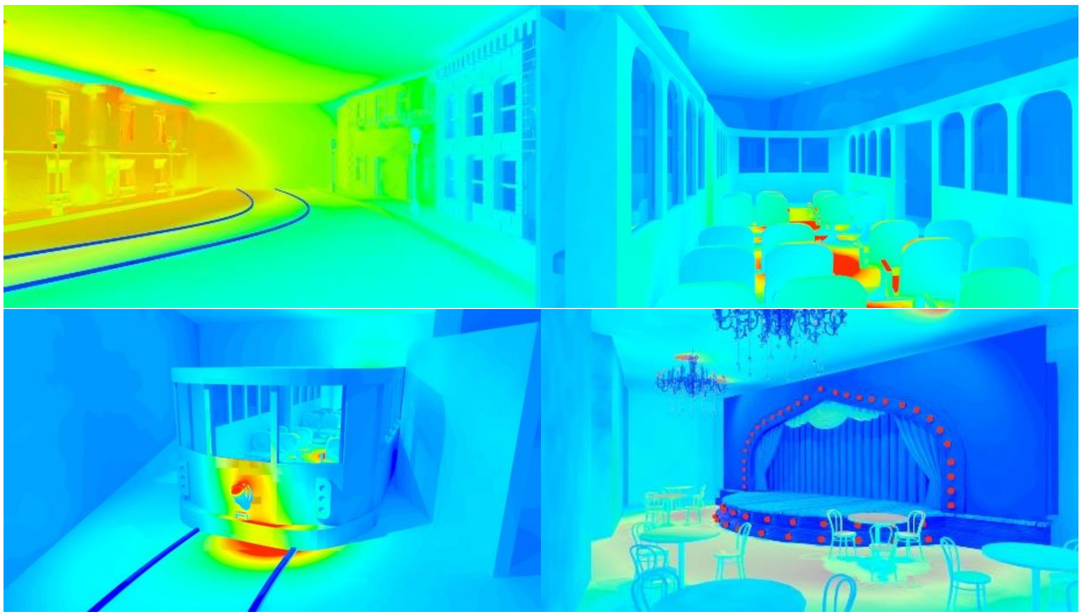

Figure 3. Example of illumination visualization

3. Interference testing through the space and installations

Projectors, which are actively used in immersive exhibitions, present difficulties in equipment selection and installation due to diverse factors such as irregularities in the surface of the installation, the overlap between multiple projectors, and brightness. As shown in Figure 2, various outcomes such as the interference between the lighting and the projector, overlapping range and position, and resolution can be predicted in advance by virtually projecting a grid pattern UV checker texture.

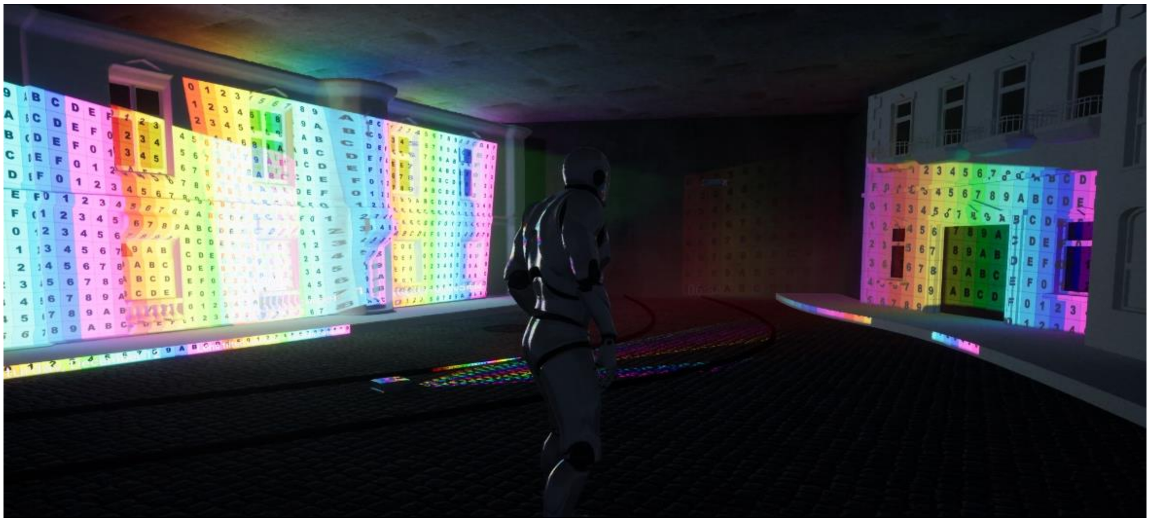

Figure 4. Interference testing process with the projector

4. Fog simulation

As shown in Figure 3, the fog can be simulated to understand the interaction between the surrounding light sources and installations. The particle range and density can be determined within the game engine, which allows the designer to predict the circumstances when the fog machine is installed in space.

Figure 5. Example of fog simulation

Conclusions

Figure 6 presents a scene of the Digital Twin outcome. In this paper, a part of the continuous research process for efficiently designing an immersive exhibition space was presented. The suggested method included interference testing through virtual space and installations by applying previsualization of real-time rendering methods, visualization of illumination due to lighting, and fog simulation, and various other visual information are able to be checked in advance. The preliminary outcomes reveal its appropriateness for planning an immersive exhibition space where complex structures and sculptures are placed and the possibility of testing various types of media exhibition contents. Moreover, the previously unattainable quality of the virtual environment could be achieved, and the degree of interaction between virtual objects in games and contents with conventional virtual reality technology could be improved. Thereby, its usability as a writing tool as well as its value as independent virtual reality contents are estimated to be obtainable. Furthermore, future applications could extend to structural projection mapping of historical investigation content and integrated regulation management of interaction media by combining various functions of previsualization using game engines.

Figure 6. Digital twin of exhibition space

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