Optimized Design of Interior Space Based on Virtual Reality Technology

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Abstract: In today's society, virtual reality (VR) finds widespread application across diverse domains, owing to its distinctive attributes of interactivity, immersion, imagination, and its capability to overcome temporal and spatial limitations. This paper centers on optimizing environmental spaces through VR technology. It offers an in-depth analysis of VR's role in enhancing environmental design, encompassing stages like preliminary investigations, conceptual auxiliary planning, detailed program design, plan execution, and construction guidance. In this process, the key technologies of virtual reality technology are explored, and finally, the paper elucidates the practical aspect by addressing the construction and optimization of three-dimensional (3D) virtual systems, emphasizing the selection of modeling tools and design process precautions as well as strategies for troubleshooting encountered challenges. This study aims to introduce innovative paradigms to environmental design, thereby enriching the design process with expanded possibilities.

Keywords: virtual reality technology; space optimization; interior design; 3D virtual system

1 Introduction

In the contemporary society, the rapid development of big data, cloud computing, Internet of Things and other technologies are coincidentally pointing to one direction: artificial intelligence(AI). The prospect of AI is exciting, and VR technology, as its important way of expression, will drive various industries to new peaks of development under the virtual representation based on real scenes. Especially in the field of interior space design, the requirement for learning and innovation is becoming increasingly significant. However, the wide range of specialized knowledge and practical skills required for environmental design are difficult to satisfy by traditional learning methods [1].

Against this background, VR technology presents great potential, especially in the field of interior design. With the help of VR technology, designers are able to access a wider learning space, which is not limited by time and place. In this paper, we will explore the application of VR technology in the field of interior design, with a special focus on its potential for developing interior design talent. This research will lead to a better understanding of how virtual VR can shape the future of environmental design education and practice.

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2 The concept, characteristics and significance of VR technology

The most global and inclusive way of defining it is as follows, "Virtual reality is defined as the experience of a perceiver of a remotely presented real or simulated environment."[2].It creates and experiences a virtual world that provides visual, auditory, tactile and other sensory stimuli to the user and enables the user to interact with the environment in real time through the relevant medium, bringing about an immersive feeling and experience.

2.1 Characteristics of VR technology

2.1.1 Interactivity

The natural interaction between the user and the virtual room is an outstanding hallmark of VR technology, which realizes multi-sensory stimulation through sensing devices such as helmet displays, data gloves, and other sensing devices, replacing the traditional mouse and keyboard .

2.1.2 Immersion

Unlike traditional screen and sound simulation, VR technology simulates the senses of sight, hearing and touch through sensors, and realizes scene transformation through the user's motion perception, thus creating an immersive feeling.

2.1.3 Imagination

Users imagine objects in the virtual room through imagination and judgment inference, and the 3D effect simulates scenes that are not visible in reality, allowing users to intuitively understand complex structures and visualize abstract knowledge. Users can also imagine the future or the microscopic world through association and logical reasoning.

2.2 The significance of VR technology for interior space design

The interactivity, immersion and imagination of VR can provide support for auxiliary design and scheme expression. It enables designers to interact with the space more intuitively, triggering new design ideas, enhancing design rationality, and improving the vividness of the space experience. At the same time, it can also realize real-time interaction with the audience, demonstrate design intent, enhance the audience's impression of the venue, and promote greater interactivity. In addition, VR technology can simulate construction scenarios and realize comprehensive site management and scheduling, so as to ensure project safety, enhance the construction level, reduce costs and resource waste, and promote sustainable development. Through VR technology, we can transcend the confines of reality, explore boundless possibilities, and achieve true optimization and flawless presentation of the space.

3 The key technology of VR technology to assist interior space design

3.1 3D modeling technology

In the next five years, with the rapid development of big data, cloud computing and the Internet of Things, more and more Internet applications will be presented to users in three-dimensional (3D), mainly covering the fields of network video, e-reading, online games, virtual communities,

e-commerce and distance education. It will even play a role in promoting the tourism industry, which can present the world's famous sights, sculptures, antiques, etc. to the user in a fascinating 3D form, and the degree of shock it gives to the user will far exceed that of two-dimensional (2D). In the field of environmental design, creating accurate, low polygon and concise documented 3D models is the ultimate goal of 3D modeling technology, and it is also the key to ensuring the effectiveness of scene models in VR systems.

3.2 Stereo display technology

One standout aspect of VR technology is its "immersive experience," wherein users feel fully engrossed in the presented scene. Stereoscopic display technology leverages the human eye's stereoscopic vision principle, complemented by auditory cues, to create a richer multi-sensory encounter, thus enhancing user perception. While the current technological and practical limitations hinder replicating the senses of smell, taste, and touch, achieving visual and auditory sensations is more feasible. Various 3D stereoscopic display techniques, such as complementary color, time-division, light-division, full-fidelity, grating, screen-viewing, and holographic methods, contribute to an augmented environmental design experience. These technologies further heighten the sense of realism, enabling users to immerse themselves in lifelike virtual scenarios, see **Table 1**.

Table 1. Chart of pros and cons of stereoscopic display technology.

Stereoscopic display technology	Pros	Cons	Areas of application
Complementary color method	No need for special glasses, adjust the color to achieve three-dimensional effect	Images may have distorted colors and are not suitable for color blind people	Scenes with simple images and low color requirements
Time division method	No need for special glasses, suitable for multiple viewers	Requires high refresh rate equipment, may cause visual fatigue	Multiplayer entertainment fields such as games and movies
Light division method	High resolution and transparency, suitable for large systems	Requires special glasses, high cost	Medical visualization, scientific research and other high-resolution fields
Totally true method	Realistic effect, immersive experience	Requires special equipment, limited viewing angle	Virtual reality games, simulation training, etc.
Raster method	High resolution, wide viewing angle, suitable for large images	Requires special glasses, may cause visual fatigue	Virtual reality display, engineering design, etc.
Screen Viewing	No special glasses required, suitable for common display devices	Restricted viewing angle, may affect the effect	Smartphones, tablet PCs, etc.
Holography	Realistic effects, no special glasses required	High technical difficulty and high cost	Scientificresearch, medical imaging, artistic creation, etc.

3.3 Real-time 3D image generation technology

Real-time 3D image generation technology plays a crucial role in the field of VR. With the rise of VR technology, there is a growing demand for real-time interaction and instant feedback from users, however, traditional static rendering methods are unable to satisfy such instantaneous requirements [3]. Especially in VR environments, time efficiency becomes critical, see **Figure 1**.

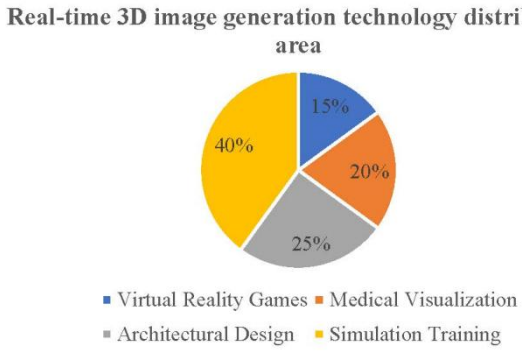

Fig. 1. Distribution map of virtual reality technology applied in different fields.

At the same time, real-time 3D image generation techniques are extremely demanding in terms of image quality and fluidity, and require a large amount of computational resources. To overcome these challenges, researchers are continuously exploring innovative real-time rendering techniques. Techniques such as ray tracing, real-time shadow generation, and hierarchical management of geometric details are gradually being introduced to balance the relationship between real-time and visual quality[4]. In addition, optimization strategies such as level detail management, streaming loading, and asynchronous computation offer new possibilities for real-time rendering. By addressing the challenges of real-time rendering, the user demand for immersive, high-quality virtual interiors can be better met.

4 Application of VR technology in various stages of interior space design

Virtual reality technology has important applications in various stages of indoor space design. At the stage of pre-program auxiliary investigation, by analyzing the terrain, the current situation of the building, etc., it provides scientific basis for the designer and decision makers. In the concept generation stage, it will establish large volume model to help designers understand the site relationship, and break through the plane thinking and deepen the understanding of spatial characteristics through the detailed auxiliary program design. When implementing auxiliary program, the panoramic viewpoint real-time interactive experience of the design intent. In the auxiliary guidance of the construction process, it can manage the whole progress and reduce the risk and waste of resources [5]. The process is shown in the **Fig. 2**.

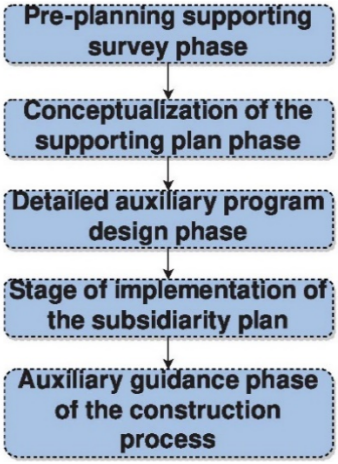

Fig. 2. Application phase flowchart.

5 Application Practice

5.1 General framework of 3D virtual system

Designers make a general framework of the project through requirements analysis of system functions, development cycle, and the software and its design [6], see **Figure 3**.

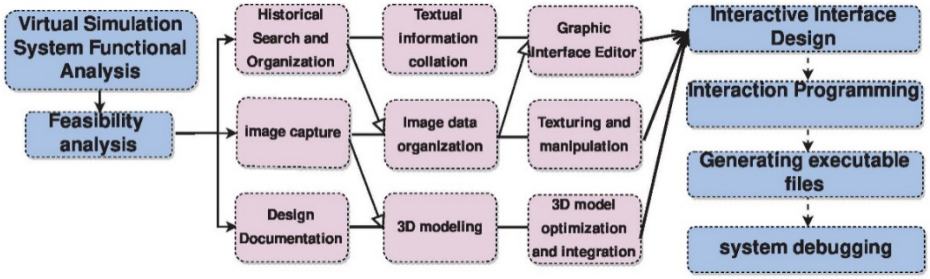

Fig. 3. Framework diagram of virtual simulation system construction process.

5.2 Project development process

The development of the 3D virtual simulation system covers multiple stages, in which the completion time of the pilot process has an extremely important impact on the subsequent work. In this project, a number of research tasks are involved, such as design document organization, picture shooting, historical document retrieval and arrangement, and 3D model generation, which will be the next step in the research work. However, it should be noted that image organization and 3D model establishment can be carried out simultaneously in this process. In addition, after part of the 3D model is completed, it can also be carried out simultaneously with texturing and other tasks. Overall, the development process of the system will fully integrate parallel and serial working methods to achieve efficient advancement of the project, see **Figure 4**.

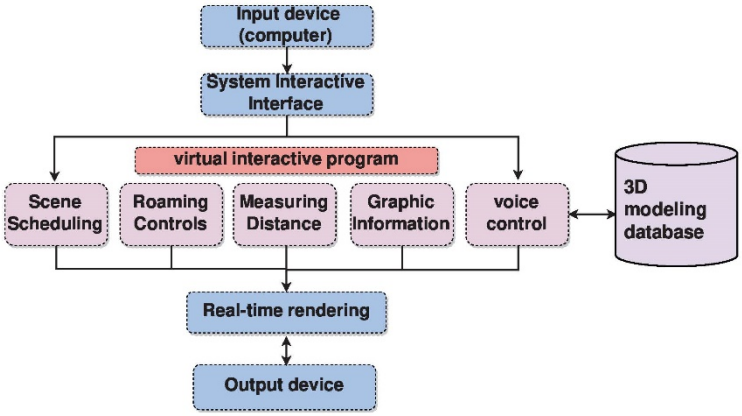

Fig. 4. Development flowchart

5.3 Project 3D model construction and optimization suggestions

5.3.1 Modeling tools

In the project stage of 3D model construction and optimization, we can consider the following modeling tools to meet the needs of different types of models in the project, see **Table 2**.

Table 2. Chart of Modeling Tool.

Modeling Tool	Applicable Fields	Features and Advantages
Autodesk 3ds Max	Architecture, Roads, Vegetation, etc.	Rich modeling tools and material library, suitable for creating detailed models
Trimble SketchUp	Initial Interior Design Concepts	Simple and user-friendly interface, quick for concept design
Rhino	Engineering, Industrial Design	Advanced geometry modeling tools and freeform curve capabilities, suitable for surface modeling
Unity 3D	Virtual Reality, Game Development	Broad engine capabilities for modeling and rendering
Autodesk Revit	Architecture, BIM	Provides Building Information Modeling (BIM) capabilities, aiding comprehensive design and construction
ZBrush	Digital Sculpting, Painting	Professional tools for detailed sculpting and model optimization
Cinema 4D	Advertising, Animation, Visual Effects	Powerful modeling, animation, and rendering tools, suitable for multimedia production

In summary, designers can use a combination of different tools to achieve optimal results and efficiency, depending on the needs of the different model types in the project. At the same time,

it is also necessary to take into account the learning curve of the tools and the investment of the required resources to make an informed decision.

5.3.2 Optimization Suggestions

5.3.2.1 Texture Streamlining

When using Autodesk 3ds Max model, we can use Photoshop to combine the texture map with the model to realize the parallel operation of the two processes. On one hand, we can make a more intuitive observation of the size and space proportion of the model in the manufacturing of the model. On the other hand, it is simple to operate and add the texture mapping directly to the plane or BOX.

5.3.2.2 Model Improvement

Once all the models are built, a series of simplifications are made and then the details are further refined to increase the realism of the scene. Importing the BIM model into the 3D engine is a challenge because some building information (i.e., material libraries) may be lost during the export and import process so more backup files have to be added. In addition, connecting multiple audio-visual devices (e.g., VR headsets) during the modeling process in order to conduct group meetings in a virtual space can enhance communication among stakeholders.[7].

5.3.2.3 Model Collapse

In order to reduce model collapse, firstly, checking the topology is the key to preventing model collapse. Make sure that the edges, faces and vertices of the model are properly connected to avoid unnecessary crossings or intersections. Secondly, repairing surfaces is an important step in solving the problem. In this stage, we can use the surface repair function provided by modeling tools to repair incorrect or incomplete surfaces, ensuring that each surface is closed.

5.3.2.4 Material Refinement

When designing, if there are problems such as materials failing to attach or being damaged, you can consider solutions from the following three aspects: Firstly, make sure that the parameters of the material, such as color, texture and reflectivity, are correctly set in the design software because incorrect parameter settings may cause the material to appear unreal or not as expected. Secondly, if you use textures to increase the realism of the material, be sure to choose high-quality textures for the reason that low-resolution or blurry textures may cause the material to be unclear.

Besides, optimizing the model is a key initiative. Complex models can lead to material refinement problems. Before material, refining, it is necessary to make sure that the model is topologically sound and does not contain unnecessary polygons or vertices.

In addition, adjusting lighting is also an important factor in material effects. Adjusting the lighting settings appropriately can improve the realism of the material.

6 Conclusions

This study deeply explores the application of VR technology in the field of interior space design. By analyzing the key elements of VR technology such as interactivity, immersion and imagination, it reveals its auxiliary role in different design stages. From the pre-planning assisted investigation to the conceptualized assisted scheme, to the detailed assisted program design and the assisted guidance of the construction process, VR technology provides an innovative method to optimize the spatial design. In terms of application practice, emphasis is placed on the construction and optimization of 3D virtual systems, as well as the selection of modeling tools and problem handling during the design process.

However, despite the great potential of VR technology in interior design, we should also recognize some problems and shortcomings. Firstly, the high budget of VR technology may limit its wide application in some projects. Secondly, the rapid development of the technology may lead to the need for designers to continuously learn and adapt to new tools and platforms, increasing the difficulty of practical application. In addition, VR technology still has limitations in simulating real sensations and may not be able to completely replace the experience of real space. Despite these problems and shortcomings, these challenges also provide us with new research directions and room for improvement. By overcoming these obstacles, VR technology will hopefully further expand its application in the field of interior design and improve the efficiency and outcomes of the design process. In the future, VR technology will continue to play its positive role in the field of interior design, contributing to the creation of better quality, creative and practical space design.

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