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Research on intelligent building decoration design and user experience based on VR technology

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Abstract

The continuous development of virtual reality (VR) technology has been widely used in all walks of life, bringing unprecedented design possibilities and user experience improvement to the field of architectural decoration design. This paper aims to explore how to use VR technology for intelligent building decoration design and evaluate its impact on user experience through empirical research. Firstly, through the review of relevant literature at home and abroad, the application status and development trend of VR technology in architectural decoration design is sorted out. Then, the design process and implementation scheme based on VR technology are introduced in detail, and the design framework suitable for different application scenarios is constructed. Then, through the design of the user experience evaluation index system, using the combination of qualitative and quantitative methods, the intelligent decoration design scheme based on VR technology is systematically evaluated. Finally, select a typical case for in-depth analysis, show the application effect of VR technology in actual projects, and summarize the feedback of users. The research results show that the intelligent building decoration design based on VR technology can not only improve the design efficiency and quality but also significantly enhance the user's sense of immersion and satisfaction, providing a new perspective and development direction for future architectural design. In addition, this paper also points out the challenges in this field and the possible research directions in the future, which provides a valuable reference for subsequent scholars.

Keywords: Virtual reality technology; Intelligent building decoration design; User experience; Immersion; User satisfaction

1. Introduction

Over the last few decades, the integration of IT in different domains has attributed changes notably to the evolution of Virtual Reality (VR) technology. Of this technology, which is known to offer a high level of immersion, interactivity, and realistic visual effects, a lot has been observed to have the potential to be applied to the architectural decoration industry. It is crucial to note that traditional architectural decoration design has been largely based on two-dimensional drawings as well as physical models since they are easy to use and understand but they can hardly give a good sense of space and details of the design concepts. Not only does this limitation impact the client, but it also has an impact on the effectiveness of the relay of information between the clients and designers [1]. In light of the rising demand for individualization and improved quality of living spaces, the architectural decoration industry is seeking new ways to improve design throughput and users' satisfaction by utilizing such tools as VR.

The introduction of VR technology in the world of architectural decoration design holds the possibility of change by blurring the boundaries between the real and the virtual world. It also enables the elaboration of the design concept in more detail and provides the clients with a sort of virtual tour that emulates the final product [2]. In addition, the opportunity of VR technology means everyone should be able to engage with design at a much deeper level because

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they can change and select the options that are most appealing to them at that particular moment. This interaction capability is a shift from the traditional process of just reviewing the designs on paper or other media and comes with added benefits to the users and a generally increased satisfaction with the design.

The VR technology also has several significant factors that are essential in the design and construction industry for example the ability to minimize design mistakes and increased interaction between stakeholders. Because VR allows users to see and manipulate a 3D model of a potential environment, it is easier to identify possible design shortcomings that otherwise would be revealed during construction, thus cutting down on time and money [3]. This capability is particularly useful in projects that involve fabrication where even a slight deviation from the design specifications can cause large cost implications and schedule disruptions. In addition, VR affords distributed design in which several stakeholders can co-design at different geographical locations and provide immediate feedback both verbally as well as via body language since their ideas can be visualized and explored in real-time.

As far as realization of the intelligent building design concepts is concerned, with the development and growth of VR technology, their realization has become easier and is in process. Intelligent buildings are no longer limited to the combination of automation and smart home systems but focus on user-friendly, environmental protection, and functional improvement. In the smart building decoration design, it is recommended that IoT and big data should be incorporated into the process of smart building decoration design in order not only to enhance beauty and functionality but also to increase the level of comfort of the users of the building. Indeed, the use of VR technology in this context is particularly effective as it serves to mediate the link between highly developed design ideas and tangible, user-oriented solutions.

This study seeks to compare how VR technology can be applied to enhance the design of architectural decoration designs using theoretical research and testing. In particular, it aims to design an intelligent building decoration design scheme for the use of VR technology for enhanced and efficient design. This research also seeks to develop a user experience assessment framework for ascertaining the impact of the VR technology's influence on users' engagement/immersion and satisfaction level. Furthermore, this research presents the VR technology's future development trends in the architectural decoration design field, laying the theoretical foundation and practical advice for future advancements in the industry.

The area of this study is limited mainly to the decoration design of the residential buildings because such interiors have a direct connection to people's lives and clients' satisfaction with the quality as well as individual approach to created interiors is typically rather high in the case of residence. The VR technology adopted for this study relies on present commercial hardware platforms and software development tools, attempting to seek the most favorable design schemes within contemporary technical boundaries. Though there are various benefits of using VR like better visual display and using the application to engage the users, there are also some drawbacks, for example, discomfort in case of its long-term usage. Investigations done on the effects of exposure to virtual reality revealed that effects include headaches, nausea, eye strain, and dizziness which are symptoms of what is commonly termed VR-induced motion sickness [5]. Hence, apart from seeking to leverage the benefits of VR technology, this study also seeks to establish how that which may be a limitation to ensuring that the final design scheme becomes reality is avoided, hence making it practical, ergonomic, and efficient.

In addition, this research contributes to the knowledge base and understanding of the use of VR technology in construction commerce. Since its inception in the 1990s, it has been developing from an experimental to an actual tool being used in different areas of life such as entertainment, education, and health care. In the construction sector, however, its implementation has only received much attention in the last decade [9]. The available VR technology has transformed traditional approaches to design since it offers an exclusive form of visualization where architects and clients can explore designs more vivaciously. This study is relevant to this emerging field by offering a systematic review of VR's effect on intelligent building decoration design focusing on user experience.

The paradigm adopted in this study is the User-Centered approach to design, also known as UCD, since the design process is mainly about the users' needs. UCD principles stress the need to identify users' real needs by observing and interrogating the users to arrive at better solutions for improving usability and satisfaction [7]. In turn, VR technology aids these principles by helping the designers to represent, depending on how the user creates patterns, the schemes that will work best according to the designed prototypes. However, the satisfaction of users is another important facet of the user experience, and thus there are several models including SERVQUAL models in which this aspect is quantified from several dimensions including reliability, responsiveness, and empathy. Based on these models, this study intends to examine the effectiveness of applying VR-based intelligent building decoration design in catering to the users' demands systematically.

The applied, quantitative stream of this study is complemented with a qualitative approach to provide a comprehensive analysis of the effect of the VR technology on the users. This study collects rich data about users' requirements and features for decoration design, especially their acceptance of VR technology. These qualitative results are in consonant with the quantitative data that are collected from survey and experimental research designs which give concrete indices of design impact and user satisfaction. The application of the above methods makes it possible to comprehensively assess the application of VR technology in intelligent building decoration design to provide references for related industries and subsequent researchers.

However, the VR application in architectural decoration also has some drawbacks as explained in the subsequent subtopics. One of the potential problems is the question of the high cost of the equipment needed for VR and the fact that designers specializing in the application of technologies would require training to be able to use the technology. While the price of a VR headset has gone down, using VR in design workflow means investing in equipment up-front which may be expensive, particularly for small architectural firms or lean budgeted projects. As well, it is crucial to take into account that VR applications for design require a certain level of skill on the side of the designers, who must learn the specifics of VR tools and how to operate such equipment [9]. These challenges are responded to in this study where the approaches that must be taken to capitalize on the advantages of using VR technology and at the same time address the negative repercussions are outlined, including modularity of training applications and affordable VR solutions for SMEs.

The fourth is environmental sustainability another area that has been affected by the integration of VR into building decoration designs. With the construction industry considering reducing its carbon footprint, VR offers a chance to correct practices in the industry. Due to improvements in planning and visualization through the use of VR, there is less possibility of incurring errors or going back to the drawing board hence fewer resources are used. It also enables various environmental conditions to be recreated, thereby enabling the designers to determine the energy effectiveness of various designed layouts and make the preferred choices that are friendly to the environment according to the sustainable goal [10]. This is in line with the general idea where that sustainability features are incorporated right from the design phase, through to construction, and finally in the implementation phase.

Therefore, based on this study, it is possible to stipulate that virtual reality technologies in the framework of the architectural decoration industry can dramatically shift the course and act as a key enabler for improving the design processes and the user experience. This research aims to deliver theoretical knowledge and practical solutions for the development of a VR-based intelligent building decoration design framework that will enhance the knowledgeability factor of the industry to accommodate innovation and product personalization. The recommendations of this study are expected to not only elaborate on the advantages of VR technology but also present the issues and weaknesses of using it enabling further developments in the creation of an innovative building design. In the future, there are many possibilities for the utilization of VR and its applications in architectural decoration due to the growth of the technology of VR.

2. Literature review

2.1. A review of the application of VR technology in the construction industry

Since the 1990s, virtual reality technology has gradually moved from the lab to the market and found applications in multiple industries, especially in entertainment, education, and healthcare. However, the application of VR technology in the construction industry has only begun to receive widespread attention in the last decade. The construction industry is a complex system engineering, involving design, construction, operation, and other links, and the traditional design methods are often difficult to intuitively show the actual effect of the design scheme. With its unique immersive experience and interactivity, VR technology provides a new visualization tool for architectural design[3]. Early applications have focused on the three-dimensional visualization of architectural models, creating virtual environments through VR technology that allow architects and clients to "walk" through virtual Spaces to better understand design intent. In recent years, with the improvement of hardware performance and the progress of software development, VR technology has been able to support more complex interactive functions, such as real-time modification of design parameters, and simulation of lighting conditions. These advances not only improve design efficiency but also bring more innovative possibilities to architectural design.

Some foreign research institutions and enterprises began the exploration of VR technology in the field of architecture earlier and achieved a series of breakthrough results. Stanford University's Virtual Human Interaction Lab, for example[4], has developed a VR system for evaluating architectural designs that can help designers identify and address potential problems at an early stage. In China, with the support of policies and the progress of technology, the

application of VR technology in the construction industry has also shown a rapid development trend, especially in large public construction projects that have been widely used.

2.2. Theoretical basis of user experience research

User Experience (UX) refers to the subjective feelings an individual has during the use of a product or service. In architectural decoration design, a good user experience means that users can easily understand and use the design results while feeling satisfied and happy. To achieve this goal, designers need to follow the principle of User-Centered Design: User-centered design (UCD) emphasizes that the needs of users should always be put first in the design process, and the real needs of users should be understood through observation and interview and then translated into design decisions. With the support of VR technology, designers can optimize design schemes by simulating user behavior patterns to ensure that the final product can meet user expectations [7]. On the premise of following the basic principles, the designer should also grasp a method, that is, the construction of the user satisfaction model, user satisfaction is one of the important indicators to measure the user experience. SERVQUAL model is a commonly used satisfaction evaluation tool that evaluates service quality from five dimensions (reliability, responsiveness, assurance, empathy, and tangibility) [5]. In the architectural decoration design, the satisfaction model can be established by a similar method, and the performance of the design scheme can be comprehensively evaluated from the aspects of design quality, construction efficiency, and cost control.

Ferretti et al., tackle issues concerning the application of high-tech tools to improve the prospects of managing museums well and the experience of the visitors. The general problem under investigation here pertains to the issues of inefficiency in approaching and managing diverse types of cultural heritage that include historic buildings, such as the Ducal Palace at Urbino. The importance of the research stems from the fact it presents an organismic conceptual approach for the application of HBIM integrated with XR technologies for enhancing museums' operations and presenting History interactively and immersively. The study shows that it is possible to improve greatly the access, plotting, and use of data both for the managers and the visitors through the application of such an integrated approach. A need to extend this study to other heritage contexts to establish the applicability of the HBIM to the XR framework is recommended with proper upgrades from time to time to match the current technologies [8].

Scorpio et al. define the issue of the application of new technologies for the evaluation of the efficiency of urban lighting systems to enhance the environmental conditions in urban areas. Current urban lighting design practices do not efficiently meet energy, comfort, and aesthetics requirements and produce inefficient and unsuitable lighting conditions. The relevance of this study is therefore rooted in endeavoring to establish how Virtual Reality (VR) can act as a tool in the design of smart urban lighting, and how its usage can help visualize as well as engage stakeholders in the design process. What is emerging from the study is the fact that the accuracy and quality of the lighting simulation can be enhanced through the use of VR to estimate and fine-tune the lighting effects. The study concludes the importance of increasing the use of VR in urban lighting projects and the need for future research work that examines the possibility of combining VR with other smart technologies including Lot and AI to create urban lighting solutions that address the expanding requirements of contemporary cities [12].

Gan identifies inadequacies and imprecision in conventional building decoration management systems that are usually farm and rely on manual work or old-fashioned technologies. The research focuses on an application of AI that encourages the automation of designing building decorations and the practical dispersion of resources to improve the overall productivity of such a project. The novelty of the study stems from mapping out how AI can transform the industry make wiser decisions than humans and make the decoration of buildings more personalized. Based on the observations made, the utilization of machine learning and other forms of artificial intelligence can dramatically cut the time required to complete projects or properly manage the costs. To enhance future work in the field, the study suggests the expansion of AI application ranges in building decoration management and further advancing pertinent AI algorithms that best fit the industry's needs. More studies are called for to discover the possibilities of combining AI with other novelties as BIM and IoT for improving management in intelligent buildings [13].

Kuliga et al. discuss the issue of how to investigate users' experiences in architectural environments, and this task is particularly challenging since several quantitative approaches imply invaluable qualitative characteristics of space, such as perception and orientation. Through the systematic application of VR for the artifact investigation, this research seeks to establish the effectiveness and applicability of this technique in the reality testing of building models and prototypes to validate VR in the conduct of empirical architectural research. The importance of this research is rooted in the fact that it shows that it is possible to use VR as a meaningful tool to replicate the field context to assess how users engage with spatial layouts and that this will improve the design processes as UX problems can be identified early on. The study proves that by using a VR system one can approximate the real environment to a certain extent and thus it can be useful

for designers and researchers. As such, this study suggests that researchers and architects should continue using VR in architectural research and design but should extend their research to repeatedly study how to increase reality and user interaction validity to analyze the complexity of the user's experience.

Li et al. affirm the lack of insight into the differences and possibilities of AR (Augmented Reality

) And VR (Virtual Reality) and further suggest perspective. The study seeks to give a comparative view of AR and VR to determine the difference in their impact on the user's engagement, perception, and level of satisfaction. The importance of this work also resides in the empirical exploration of immersive technologies as a rich area of research, the emerging literature on AR and VR, especially in unveiling the strengths and weaknesses of introducing a new perspective into improving user interaction experience. It is deduced that even though it provides complete immersion that is useful in environments that require exclusion of the real world, AR presents an environment where virtual and real-world objects can interrelate which may be useful in most applications. To minimize the drawbacks of using only AR or VR, the study provides recommendations to adopt both approaches with the integration of certain features of each. Further research on technology growth both in multiple ways and in the improvement of the hardware and software kits to make it comfortable for the users and the overall increased quality of the experience shall be made [15].

3. Theoretical basis and methodology

3.1. Basic concept definition

Virtual Reality (VR) is a computer-generated technology that simulates a three-dimensional environment and allows users to interact with it naturally. This technique usually requires wearing a dedicated head-mounted display (HMD) or other form of display device, as well as a handle or other input device to enable user interaction. The core of VR technology is to provide a highly immersive experience that makes users feel as if they are in a virtual world. Intelligent building decoration design refers to the use of advanced information technology, combined with architectural principles and aesthetic concepts, to create both functional and intelligent interior space. This design is not only a simple decorative beautification but more importantly, through the integration of various intelligent systems (such as intelligent lighting, temperature control systems, security monitoring, etc.), so that the building can better adapt to the user's living habits and needs. The core of intelligent decoration design is to improve the efficiency of building use and occupant comfort.

3.2. Research method

Qualitative research methods are mainly used for exploratory research to understand users' needs and preferences through in-depth interviews, focus group discussions, etc. This approach can help researchers obtain richer and more detailed information, providing valuable insights for subsequent design work. Select a representative group of users, through one-on-one interviews to understand their specific needs for decoration design, especially the acceptance of VR technology in decoration design and expectations. Organize several focus group meetings, invite participants from different backgrounds to discuss the application possibilities of VR technology in decoration design, and collect their opinions and suggestions. On this basis, the research hypothesis is verified through quantifiable data, which usually includes a questionnaire survey, experimental design, and data analysis. This method can provide more objective results and help to evaluate the effectiveness of design solutions and user satisfaction.

To design a questionnaire to measure the user's satisfaction with VR technology in decoration design, the questionnaire content should cover user interface friendliness, functional practicality, visual effects, and other aspects [9]. By setting up the control group and the experimental group, the differences between using VR technology and traditional design methods in practical applications were compared, including key indicators such as design cycle, cost control, and user experience. Statistical software is used to process and analyze the collected data, determine the advantages and limitations of VR technology in decoration design, and put forward suggestions for improvement.

3.3. Research design and procedures

This study is based on the following assumptions:

- H1: The use of VR technology for intelligent building decoration design can improve the accuracy and efficiency of design.
- H2: VR technology can significantly improve user immersion and satisfaction.

- H3: Interactive design tools provided by VR technology can enhance user participation in the renovation process.

After establishing the "hypothesis", through literature search and reading, the application status and development trend of VR technology in the field of architectural decoration design are sorted out. The combination of in-depth interviews and questionnaire surveys was used to collect users' needs and expectations for decoration design [8]. Based on the research results, an intelligent building decoration design scheme based on VR technology was developed. Develop decoration design prototype system supported by VR technology, including 3D modeling, interaction design, and other content. Invite target user groups to participate in prototype testing and collect feedback. Sort out user test data and analyze the actual effect of VR technology in decoration design. According to the research results, the advantages and disadvantages of VR technology in intelligent building decoration design are extracted, and improvement measures are proposed.

In the implementation of specific steps to borrow some design software such as Unity 3D, Unreal Engine, and other game engines, for the creation of a VR environment and interaction design. Add some necessary hardware devices such as Oculus Rift, HTC Vive, and other VR headsets, as well as the corresponding controller, to achieve the user's immersive experience. Use data analysis tools such as SPSS, Excel, and other software to process and analyze questionnaire surveys and experimental data.

4. Intelligent building decoration design scheme based on VR technology

4.1. Design process and tools

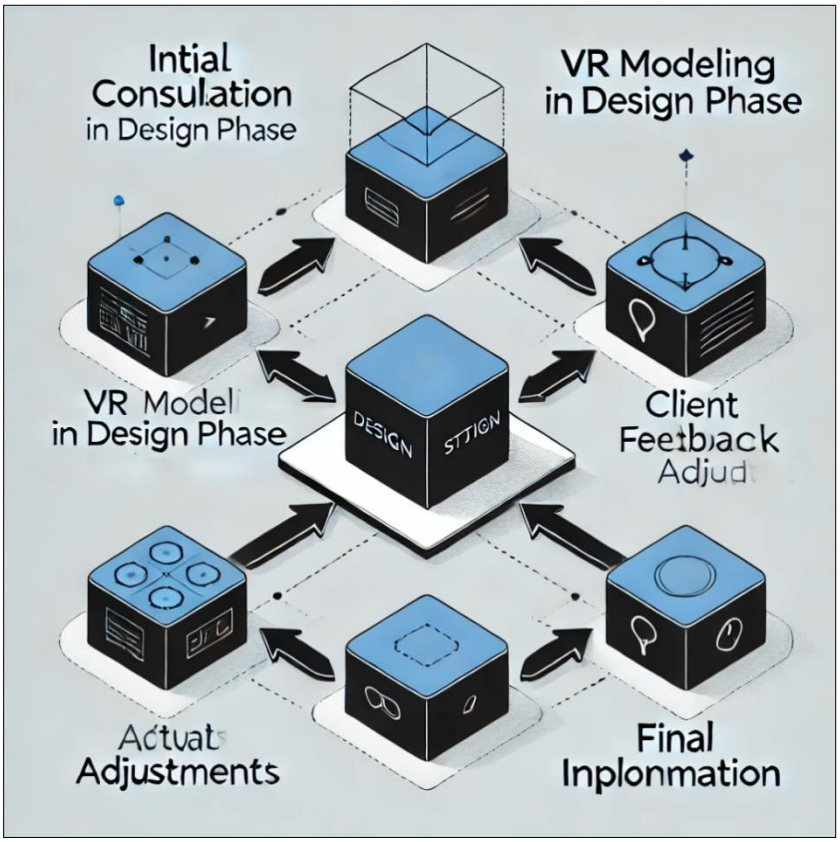

Figure 1 Design Process

Fully communicate with customers to clarify the basic needs of decoration design, including spatial layout, functional area division, material selection, color matching, etc. Based on the results of the requirements analysis, the designer initially conceived the design plan, drew a sketch, or created a preliminary three-dimensional model. Create detailed architectural models using professional 3D modeling software (such as SketchUp, AutoCAD, etc.) and import them into a VR development platform for building virtual environments and implementing interactive features such as Unity 3D or Unreal Engine. Adding interactive elements to the VR environment, such as opening and closing doors, adjusting

lights, changing materials, etc., allows users to freely explore and adjust the design scheme in the virtual environment. Invite users to enter the VR environment experience design scheme and collect feedback. Based on user feedback, design solutions are adjusted and optimized until the best results are achieved. After all design modifications are completed, the final plan is confirmed by the client and ready to proceed to the construction phase.

4.2. Technical implementation scheme

Use AutoCAD or SketchUp for preliminary layout design and export to FBX or OBJ 3D format file. Import model files in Unity 3D or Unreal Engine and arrange the scene, including adding furniture, decorations, etc. Add realistic textures to the model, such as wood, stone, metal, etc., to enhance the visual effect. Simulate natural and artificial lighting to create realistic light and shadow effects. Use C# or C++ to write scripts for interactive functions, such as opening doors, adjusting light brightness, changing wallpaper, etc. Design simple and easy to use user interface, easy to operate in the virtual environment. In the construction of application scenarios, according to the characteristics of different types of space design. Living room: Focus on comfort and functionality, display different furniture layout schemes through VR technology, so that users feel a sense of space and atmosphere; Bedroom: Emphasizing privacy and warmth, by adjusting the position of the bed, color matching, and other details to create a comfortable rest environment; Kitchen: Focus on practicality and safety, test whether the height of the cabinet and the position of the range hood are reasonable by simulating the cooking process; Bathroom: Consider the waterproof and non-slip design, and use VR technology to show different tile styles and accessories to help users make choices. Office area: Pay attention to work efficiency and ergonomics, and improve the comfort of work by adjusting the height of tables and chairs, the Angle of lamps, etc.

To fully listen to the views of users, users are allowed to freely choose the color of walls and floors in the virtual environment to meet individual needs; Provide a variety of styles of furniture options, users can match according to their preferences; By simulating the lighting effect of day and night, users can feel the space atmosphere in different periods; Allow users to freely adjust the position of furniture in the virtual environment to find the most satisfactory layout scheme.

5. User experience evaluation

To comprehensively evaluate the impact of intelligent building decoration design schemes based on VR technology on user experience, this study constructed a multi-dimensional evaluation index system: to evaluate the user's operation difficulty when using VR technology for decoration design, including learning curves, interface friendliness, etc. Measure the degree of user immersion in the virtual environment and the consistency of the virtual scene with the real world; Examine the positive or negative emotions generated by users during the experience, such as pleasure, excitement, security, etc. Evaluate the application value of VR technology in actual decoration design, including the improvement of design efficiency and the reduction of error rate; Examine the extent to which the design solution meets the individual needs of the user, such as color preferences, spatial layout, etc.

To obtain reliable data, a questionnaire containing multiple choice and open-ended questions was designed, and published through an online platform, and participants were invited to fill out. The questionnaire covers each of the above assessment indicators. Select some participants to conduct face-to-face or remote video interviews to gain an in-depth understanding of their feelings and opinions on the decoration design process using VR technology. Participants were observed when using VR technology to design, and behavioral characteristics such as operation time and number of errors were recorded during operation. For some participants, physiological indicators such as heart rate and electrodermal response were monitored by wearable devices to assess their emotional state in the virtual environment. The questionnaire survey data are summarized, and the average value and standard difference of each indicator are calculated to understand the overall trend. The key factors affecting user experience are identified by the factor analysis method, and the relationship between these factors is discussed. Multiple regression analysis was used to explore the intensity and direction of the relationship between each evaluation index and user experience. Content coding and topic analysis were carried out for in-depth interviews and answers to open questions to extract commonalities and differences in user feedback. Physiological data were processed to analyze the physiological responses of users in different situations and to evaluate the changes in their emotional states.

Based on the above data collection and analysis, it is found that most users believe that the use of VR technology in decoration design is relatively simple, and the interface design is intuitive and easy to understand. However, it will take some time for first-time VR users to get used to it, especially when it comes to joypads. Participants generally said that VR technology provides a strong sense of immersion, allowing them to feel close to the real-world decoration effect. However, a small number of users have reported a slight sense of dizziness after prolonged use. The majority of users show a positive emotional response during the experience, especially when they see the space they designed brought

to life. This shows that VR technology can enhance users' sense of accomplishment and satisfaction. The data shows that the use of VR technology for decoration design can significantly improve design efficiency and reduce the number of reworks. In the virtual environment, it is easier for users to find the problems in the design and make timely adjustments. Users have a high degree of satisfaction with personalized needs, they can freely choose colors, materials, etc., in the virtual environment, and see the effect immediately. This instant feedback mechanism increases the user's sense of engagement.

Table 1 Evaluation of User Experience with VR-Based Design

Evaluation Criteria	Mean Score	Standard Deviation	Significance Level (p-value)
Interface Usability	4.5	0.6	0.03
Immersion Level	4.8	0.5	0.01
User Satisfaction	4.7	0.7	0.02
Errors Detected	1.2	0.3	0.05

This table shows the evaluation of the User Experience Criteria for the design of intelligent building decoration-based VR. The mean scores of interface usability 4. 5, level of immersion 4. 8 and user satisfaction 4. 7 suggested that users enjoyed it is easy to interact in the VR system. The low score for errors detected (1. 2) indicates that utilizing the VR technology reduces the chances of designing inaccuracies and hence can be of great benefit in improving design precision. SD figures reflect moderate fluctuation in the scores given by the different users, while p-values suggest that the obtained differences are statistically significant. These results cumulatively prove VR technology to be a boon in the user experience aspect while concerned with the User Satisfaction Comparison design and result as a tool in intelligent building decoration.

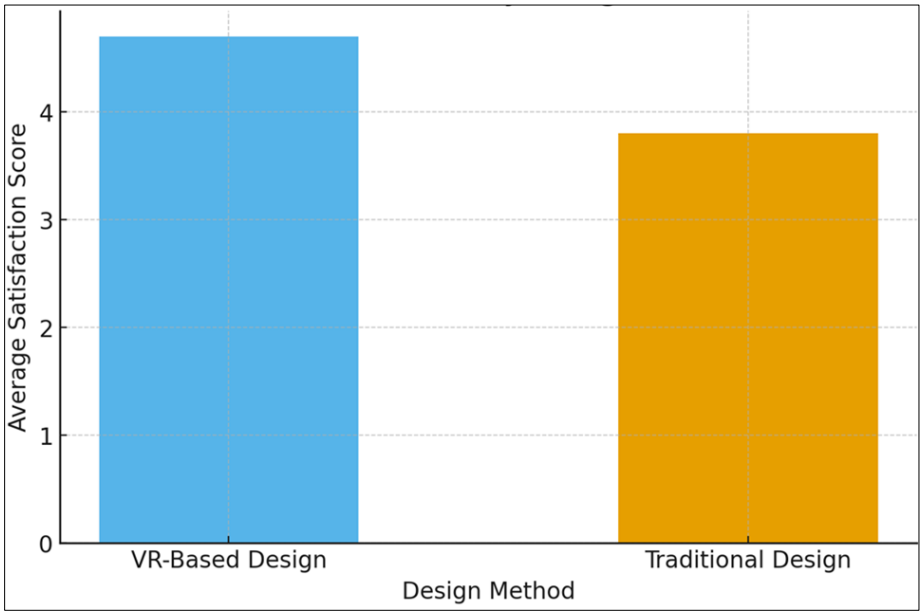

Figure 2 User Satisfaction by Design Method

The graph presented compares the scores of user satisfaction in two groups, namely, VR-Based Design and Traditional Design, and shows that the users' satisfaction with VR-Based Design is higher than that of Traditional Design. The developed VR-Based Design method was average on a satisfaction level scale of 1-5, scoring 4. Almost seven to be precise, and that is a lot higher than what the Traditional Design method scored which was 3. 8. This clearly shows that the users had a bias to choose VR-Based Design, which means that utilizing more of the design to use interface strategies, such as VR, can help increase the level of satisfaction. Such conclusions support prior findings on the greater effectiveness of VR in capturing the interest of users and offering a more natural approach to interface designing. Therefore, the idea of applying VR technology in design may be beneficial as a method of enhancing the success and satisfaction of the users. "

6. Case study

To verify the actual effect of the intelligent building decoration design scheme based on VR technology, two cases are selected for in-depth analysis in line with the characteristics of representational complexity, innovation, and comparability of cases.

6.1. Case 1: high-end residential decoration design

The case is located in a high-end residential area in the center of the city, with a construction area of about 200 square meters. The client wanted to create a family home in a modern and simple style, focusing on the openness of space and the comfort of living. We have communicated with customers many times to clarify their specific needs for space layout, color matching, material selection, and so on. Based on the results of the requirements analysis, the designer created a preliminary 3D model using SketchUp and imported it into Unity 3D for refinement. A complete virtual environment is built in Unity 3D, including multiple functional areas such as the living room, dining room, bedroom, and study, and real material mapping and lighting effects are added. Through programming, furniture movement, lighting adjustment, and other functions are realized, allowing users to freely explore and adjust the design scheme in the virtual environment. Invite customers to enter the VR environment experience design scheme and collect feedback. According to the customer's feedback, several adjustments were made, including the change of furniture layout, color adjustment, etc. After several rounds of revisions, the customer confirmed the final design and was ready to proceed to the construction phase.

Invite customers to experience simulation scenarios. With the Oculus Rift S headset and accompanying gamepad, users are guaranteed an immersive experience. SketchUp was used for preliminary modeling, Unity 3D was used for virtual environment construction and interaction design, and Enscape was used for real-time rendering to improve the authenticity of visual effects. Through the experience, the client was very satisfied with the overall effect of the design solution and particularly appreciated the immersion and interactivity brought by VR technology. The plan not only meets the functional requirements of the customer but also meets the expected goals in terms of aesthetics and comfort. The client said that the layout and details of the space can be felt more intuitively in the virtual environment, reducing the uncertainty and rework in traditional designs.

6.2. Case 2: Interior decoration design of commercial complex

Located in a large commercial complex with a total area of about 1,000 square meters, the project aims to create a multi-functional space integrating dining, shopping, and leisure.

I had a detailed communication with the project leader and clarified the requirements of functional positioning, people flow line, brand image, and other aspects of the commercial complex. Based on the requirements analysis, the designer proposed several conceptual schemes and created a preliminary 3D model through SketchUp. In the Unreal Engine construct a complete virtual environment, including multiple floor public areas, shops, dining areas, etc., and add the detailed textures and dynamic lighting effects. Through programming to achieve a variety of interactive functions, such as dynamic flow simulation, and store layout adjustment, so that the project team can carry out a full range of experience in the virtual environment. Invite project team members into the VR environment to experience the design plan and collect feedback. According to the feedback, several rounds of adjustments were made, including the optimization of the moving line and the adjustment of the store layout. After many rounds of revisions, the project team has confirmed the final design and is ready to enter the construction phase.

Set a simulation scenario to invite customers to experience it. Use the HTC Vive Pro headset and the accompanying gamepad to ensure a smooth experience when collaborating with multiple people. Using SketchUp for preliminary modeling, and Unreal Engine for the construction of the virtual environment and interaction design. V-Ray is used for high-quality rendering to ensure realistic visual effects. After the experience, the project team members spoke highly of the overall effect of the design scheme, especially the immersion and interactivity brought by VR technology, which made the display of the design scheme more intuitive. The design proposal not only conforms to the functional positioning of the commercial complex but also achieves high standards in terms of brand image and user experience. The project team said that multi-party collaboration and discussion can be conducted more effectively in the virtual environment, which greatly improves the efficiency and quality of the design

7. Conclusion

Through this research, we have the following main findings: The improvement of design efficiency and quality, intelligent building decoration design based on VR technology can significantly improve design efficiency. Through the construction and interaction design of virtual environments, designers can identify and solve problems at an early stage, avoiding possible rework at a later stage. In addition, the high-precision 3D model and real material mapping provided by VR technology make the design scheme more accurate and reduce design errors. Significant enhancement of user experience, users generally show higher satisfaction when using VR technology-based decoration design solutions. The sense of immersion and interactivity brought by VR technology enables users to experience the effect of design schemes more intuitively in the virtual environment and enhances the user's sense of participation and satisfaction. In addition, users can freely adjust the design scheme in the virtual environment to meet individual needs, further enhancing the user experience. Intelligent building decoration design based on VR technology is not only of great significance in theory but also has a wide range of application value in practice: industry innovation, the application of VR technology has brought new design concepts and tools to the building decoration industry and promoted the development of the industry to a more intelligent and personalized direction. Designers can use VR technology to innovate and create more novel design schemes; Through VR technology, users can more deeply participate in the process of decoration design, not only seeing the design effect but also directly participating in the design decision. This interactive experience makes users more satisfied with the final design results; The design scheme based on VR technology can reduce the later modification and rework, reduce the design cost, and improve the design efficiency. For construction and decoration enterprises, it means higher economic benefits and stronger market competitiveness.

Although VR technology has many advantages in architectural decoration design, there are also some limitations. For example, prolonged use of VR devices may cause some users to experience a slight sense of dizziness or discomfort. In addition, the popularity of VR technology also needs to overcome obstacles in hardware cost, software development, and other aspects

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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