Research and Analysis of Interior Design Based on XR (MR-centered) Technology

Jingyi Peng

College of Arts, Hunan University of Information Technology, Changsha, China
PrinceCharming178@outlook.com

Abstract. Extended Reality (XR) is gradually applied to the field of interior design. It provides a new visual way for interior space design, enabling to preview the design effect in real space. In order to improve the convenience and intuition of interior decoration, this study designed an interior design system framework using Mixed reality (MR). Users can carry out interior decoration more easily and efficiently. Headgear system obtains real indoor spatial data based on spatial mapping technology. Generate a 3D spatial mesh model that supports real-time modification and effect preview. The generated 3D scene is superimposed into real space by MR, Users can see the virtual furniture and decoration effect in the real environment. Users can more intuitively judge the decoration size, placement position and overall space effect by moving in the room and observing the design scheme from different angles. This study provides a new scheme for XR interior design and a reference for the development of lightweight interior design tools. It is hoped that the further integration of XR in the field of home decoration can be promoted in the future.

Keywords: Extended reality, Interior design, User experience, Mixed reality

1. Introduction

Traditional design methods mainly rely on two-dimensional drawings. With the continuous improvement of people's requirements for living environment, The traditional interior decoration method has gradually emerged due to the cumbersome process and users' difficulty in perceiving the space effect. It is difficult for users to meet their needs. Interior design needs a more intuitive and simple visual way. XR develops rapidly and is gradually applied in the field of architecture and interior design. For example, some virtual reality systems have been used for virtual viewing and interior design scheme display, Users can browse and experience the design effect in a three-dimensional environment.

Research has proposed a virtual reality based interior design system (RedesignUS), Users can design in the virtual environment. The system plays a positive role in spatial understanding and user participation [1]. Darwish et al. Compared the application of XR technology and traditional design tools in architectural design education through experiments, The results show that XR can effectively improve users' understanding of spatial structure [2]. XR provides a new way for spatial presentation. Users can more accurately and intuitively feel the spatial scale and the overall effect. Improve the fault tolerance rate of the design process and save the decoration time and energy.

Pintani et al. Carried out collaborative indoor research, and realized the placement and editing of virtual furniture by multiple people in the real scene through the management hierarchy and submission mechanism. The feasibility of the system is verified by user experiments. It provides important support for the research of interior design in the real environment [3].

Although XR technology has been applied in the field of interior design display and spatial visualization, most existing systems rely on virtual modeling environment for scheme display. Users usually need to browse the design effect in the built 3D model. Before use, it is often necessary to establish or import the house model in advance and display it in the fixed equipment environment. When the space is large, users mainly rely on the controller for virtual movement and view switching. When the visual movement is not synchronized with the body movement perceived by the vestibular system, it is easy to cause VR cybersickness [4]. When the design scheme changes, it is often necessary to update the model or reload the scene, which increases the process cost of design presentation and scheme adjustment.

To improve the efficiency of interior design scheme and reduce the burden brought by virtual navigation. This study proposes a framework of interior design system based on XR. This framework is based on superimposing virtual design content in real space. This framework is based on superimposing virtual design in real space. Users can observe the overall effect in Natural Locomotion (NL) in real space. NL produces less dizziness than controller based locomotion [5]. This system can complete spatial display and rendering in a single device environment, reducing the steps of computer modeling and scene import in most processes. This system provides a more humanized and efficient solution for the interior design process.

2. Methodology

2.1. Concept source

In the process of interior decoration, users generally have the need to preview the design effect in advance and perceive the real space. Traditional design methods usually rely on two-dimensional drawings or limited three-dimensional display to understand the spatial layout. This method puts forward higher requirements for users' spatial imagination ability, which is easy to lead to design understanding deviation and decision uncertainty. In addition, the expression of design schemes is often dominated by designers, with low user participation. XR can improve users' understanding of spatial structure and spatial relationship, and is gradually applied to the field of architectural design and spatial visualization [2].

The interior design display method of Augmented Reality (AR) has been widely used in the field of spatial visualization. Users can view the 3D space layout effect through intelligent devices, so as to visually preview the design scheme. However, this method is more manifested in the overall observation of the space, and users usually view the design effect from an external third perspective. Users still lack immersive first view experience, and it is difficult to form a continuous perception process in space. Based on this application form, this study further considers the introduction of MR technology to enable users to overlay virtual design content in real space, so as to obtain a space experience closer to the real environment. Compared with fully immersive VR environment, Mr can retain users' perception of real space and reduce the discomfort caused by environmental isolation. Different virtual locomotion methods will also have an impact on the user experience. NL can usually provide a more comfortable space experience. Compared with the movement mode based on handle or transmission, it is less likely to cause discomfort such as motion sickness [4]. In VR environment, the inconsistency between visual motion and actual body motion is considered to be one of the main reasons for cybersickness [4]. These studies provide a theoretical and technical reference for the application of MR technology in interior design visualization. Therefore, this study chose to build a visualization system of interior design based on MR technology combined with natural walking mode. In order to ensure the sense of immersion and improve the comfort of users' space experience.

2.2. User perspective process

By dividing the typical use process from the perspective of users, this study analyzes the potential experience and operation problems of users in the process of interior design in three stages. Provide basis for subsequent system design.

The first stage before the design stage is scheduled to be the preparation stage. The preparation stage of some VR applications usually relies on building a complete virtual model first, and then configuring the material and furniture appearance for the model. Crolla and Sheikh pointed out that VR based design systems usually rely on specific modeling and visualization environments for content construction and interaction [6]. This increases the complexity and operation threshold of the system to a certain extent. Based on this environment, the process is cumbersome and the user's freedom of adjustment is limited, which reduces the user's sense of experience.

The second stage in the middle of the design stage is scheduled to be the design stage. Users want to adjust the layout, material or furniture configuration, but they still need to frequently rely on drawings or communicate with designers for simulation. Most of the existing interaction modes are mouse or handle operation, the spatial experience is discontinuous, and the user participation and operation efficiency are limited.

The third stage in the middle of the design stage is scheduled to be the decision-making stage. Although the existing VR system has the characteristics of immersion, it is completely based on virtual environment and lacks situational correlation with real space. Previous studies have shown that AR and MR can help improve users' spatial understanding and situational cognitive ability by superimposing virtual information in the real environment [7].

Through the first perspective immersion experience, NL and superimposing design content in real space, the paper hopes to improve users' sense of space understanding, design efficiency and design experience.

3. System design

3.1. System framework

The system consists of four parts: input, processing, output and interaction. Figure 1 shows the overall system architecture. After entering the target space in the input phase, the system scans and identifies the environment. This process is based on spatial mapping and Simultaneous Localization and Mapping(SLAM)to obtain the geometric information of indoor space, such as walls, floors and spatial boundaries. And complete pose estimation and environment mapping synchronously during the movement [8]. In the processing phase, the system analyzes and models the obtained spatial data. Among them, spatial layout analysis is used to identify the spatial structure relationship and regional division. The system relies on the capabilities of depth sensing and motion tracking (e.g., LiDAR or depth camera) to acquire spatial geometric information. SLAM method based on structured light obtains depth information through projected fringes, can realize three-dimensional measurement with millimeter-level precision, and completes real-time spatial reconstruction during movement [9]. On this basis, generate spatial mesh model (spatial mesh) [10]. This model is reconstructed from 3D point cloud, and can acquire structural information such as wall, ground and spatial boundary. Used to align virtual content with real environment. The user performs browsing and operation through six degrees of freedom (6DoF) to achieve real-time feedback.

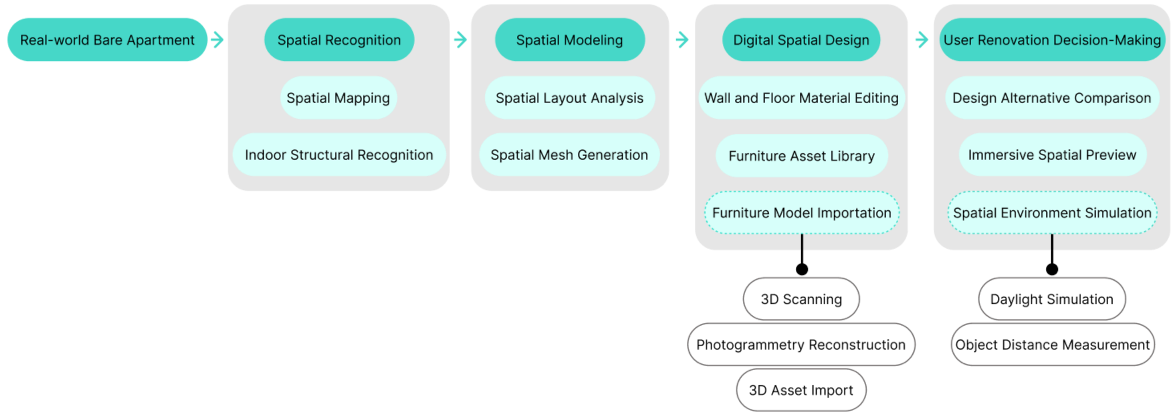

Figure 1. MR interior design visualization system architecture (picture credit: original)

Both the output phase and the interaction phase belong to the user independent operation part. The output phase corresponds to digital spatial design. Users choose to overlay the decoration scheme in the environmental model to realize the visual presentation of the decoration scheme. The system supports editing of wall and floor materials, and provides furniture asset library for soft installation configuration. Soft decoration supports furniture model import. The system realizes the layout and display of custom furniture through 3D scanning, photometry reconstruction and 3D asset import. The essence of the interaction phase is the decision support part. This stage corresponds to user innovation decision making, providing users with immersive experience and decision support. The system supports immersive preview and comparison of multiple decoration schemes. The environment simulation part of the system helps users evaluate the design effect through daylight simulation and object distance measurement. The calculation and visualization of indoor light distribution are realized by daylight simulation. The physical lighting model [11] based on radiance engine can numerically simulate the propagation process of natural light in indoor space, so as to obtain the lighting distribution results under different time conditions. In the process of spatial analysis, the system supports the acquisition of the relationship between object distance and scale. LiDAR-based SLAM method acquires spatial point cloud data through laser ranging [12], which can be used for object size measurement and indoor geometric structure modeling. The framework realizes the continuous process from spatial identification to design generation and decision-making, and ensures the structural connection between each stage.

3.2. Prototype design and interface

This study designed a system for interior decoration design. The system is based on the mixed reality environment and supports the visual presentation and user operation of the decoration scheme. The system mainly includes material editing, furniture configuration, scheme evaluation and other functions to assist users in completing the interior design and decision-making process.

After entering the target space, the user wears the head display device and looks around the environment to complete the space scanning, and the system generates the corresponding environment model. In this model, users can perform design operations in the current space through gesture interaction. People can edit the space material and furniture layout, and import or select the soft decoration configuration. As shown in Figure 2, the user can edit and adjust the color, material and size of the floor material after selecting it in the floor level. As shown in Figure 3, the user can move and rotate the furniture after selecting the bed category in the furniture level. In addition, the system supports importing custom furniture models through scanning.

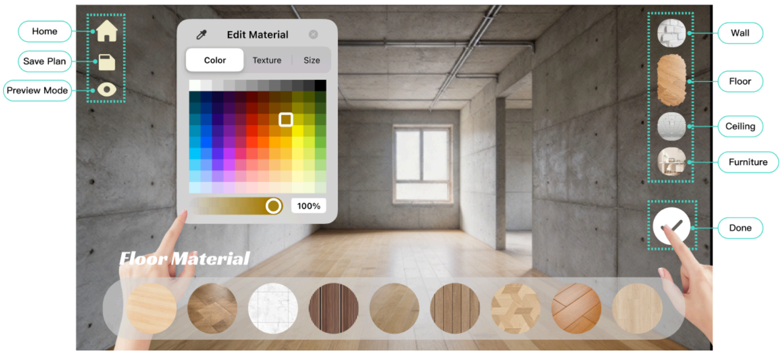

Figure 2. Material editing interface (picture credit: original)

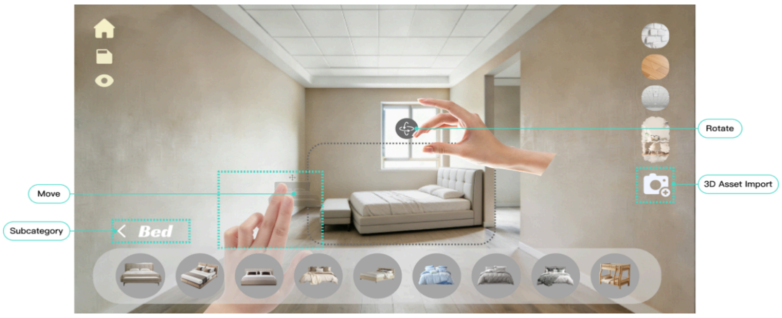

Figure 3. Furniture layout editing interface (picture credit: original)

Compared with the traditional design process relying on virtual modeling environment, this process does not need to build a complete model in advance, which reduces the complexity of operation and improves the continuity of design. After completing the design, users can preview and compare different decoration schemes in the real environment. Combined with environment simulation, the design effect is evaluated to help complete the design decision. As shown in Figure 4, the system provides sunshine simulation and object distance measurement functions, enabling users to intuitively obtain the spatial lighting changes and the distance relationship between furniture.

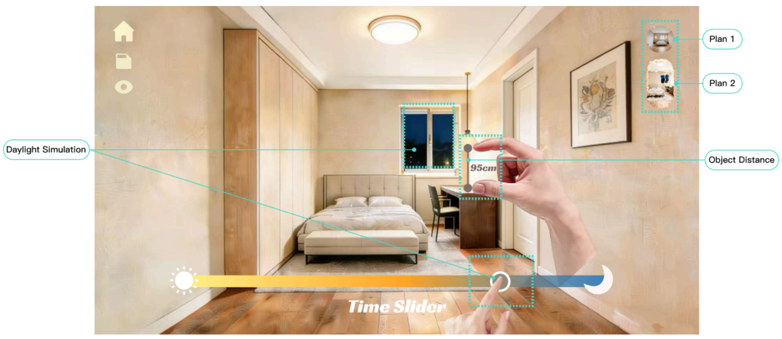

Figure 4. Environment simulation interface (picture credit: original)

3.3. Expected results

In the home interior decoration design scene, the system can present a complete decoration scheme in the real space. Users can intuitively feel the overall layout. As shown in Figure 5, the design results can be directly superimposed on the real environment to realize the visual display of the design effect. Compared with the traditional virtual design method, the use threshold of the system is lower. Users can design and adjust more flexibly.

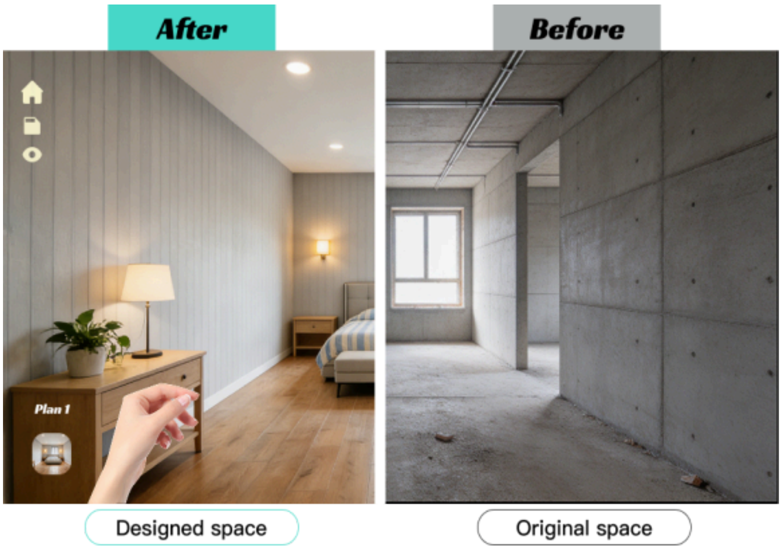

Figure 5. Residential interior design results (picture credit: original)

Figure 6. AR-MR comparison for furniture exhibition (picture credit: original)

In the display scene of furniture and household products, the traditional mobile ar application is usually based on a single furniture display. It is difficult to support the overall layout of multiple furniture. As shown in Figure 6, the system supports multi furniture combination display in real space. Limited by the screen size of mobile devices, traditional AR is difficult to fully present the overall layout effect. Compared with the mobile terminal AR, this method improves the spatial understanding ability and enhances the integrity of the display effect.

4. Conclusion

This study constructed a set of interior design visualization system framework based on XR technology, and completed the system prototype and interface process design. The prototype supports superimposing virtual design schemes in real space. The system realizes the visualization of spatial layout, decoration style and material effect. Through immersive space preview, users can intuitively understand the design scheme in the real environment. This study provides a reference direction for the application of XR in the field of interior design.

This study still has some limitations. The system depends on the performance of the equipment, and the spatial recognition accuracy may be affected in complex environments, and has not been verified by user experiments. Future research can further carry out user testing, optimize system accuracy and interaction mode, and expand its application in interior design.

References

[1] You, W., Shao, Y., Zheng, Z., Lu, Y., Yang, C., Zhou, Z., Sun, L. (2023) Old house new home: Facilitating interior design with RedesignUS in virtual reality. Displays, 80, 102555.

[2] Darwish, M., Kamel, S., Assem, A. (2023) Extended reality for enhancing spatial ability in architecture design education. Ain Shams Engineering Journal, 14(6), 102104.

[3] Pintani, D., Caputo, A., Mendes, D., Giachetti, A. (2025) Layer-based management of collaborative interior design in extended reality. Behaviour & Information Technology.

[4] Ng, A. K. T., Chan, L. K. Y., Lau, H. Y. K. (2020) A study of cybersickness and sensory conflict theory using a motion-coupled virtual reality system. Displays, 61, 101922.

[5] Boletsis, C., Cedergren, J. E. (2019) VR locomotion in the new era of virtual reality: An empirical comparison of prevalent techniques. Advances in Human-Computer Interaction, 2019, 7420781.

[6] Crolla, K., Sheikh, A. T. (2025) Grasshopper VR: Development of an immersive visualisation interface for parametric design workspaces. Virtual Reality, 29, 133.

[7] Lee, J., Kim, Y. (2025) Extended reality in architectural and interior design curricula: A review of applications, outcomes, and pedagogical implications. Design Studies, 101, 101359.

[8] Ress, V., Zhang, W., Skuddis, D., Haala, N. (2024) SLAM for indoor mapping of wide area construction environments. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, X-2-2024, 209-216.

[9] Zhao, Y., Zhang, X., Li, Z., Wang, H. (2023) FPP-SLAM: Indoor SLAM based on fringe projection profilometry. Optics Express, 31(4).

[10] Wang, W., Wu, R., Dong, Y. (2024) Research on indoor 3D semantic mapping based on ORB-SLAM2. Applied Sciences, 15(20), 10881.

[11] Reinhart, C. F., Walkenhorst, O. (2001) Dynamic RADIANCE-based daylight simulations for a full-scale test office with outer venetian blinds. Energy and Buildings, 33(7), 683-697.

[12] Süleymanoğlu, B., Soycan, M. (2022) Indoor mapping: Experiences with LiDAR SLAM. ISPRS Archives, XLIII-B1-2022, 279-284.