

Expanding Reality and Interactive Systems: New Paths to Hybrid Design Shaping the Future of Architectural Designs

Yinuo Dong

School of Architecture, University of Liverpool, Liverpool, L69 3BX, UK

Abstract: With the rapid evolution of information technology, Extended reality (XR) technology and interactive solutions play an indispensable driving force in contemporary architectural design innovation. The purpose of this article is to examine how XR technology and its integration with interactive interfaces can reshape the forward trajectory of future architectural artistic visions. The initial chapter elaborates the theoretical framework of XR and traces its historical evolution. Subsequent chapters point to multiple practices of interactive systems in the design of built environments, especially the utility of touch interfaces, hand motion recognition, and voice-controlled operations. We then delve into the deep integration of XR and interactive systems to illustrate how these cutting-edge tools work in tandem, further demonstrating their potential to improve design quality and engineering efficiency. In the following part, we use case analysis and empirical design to confirm the function of XR technology and interactive solutions in real design situations. The final discussion focuses on the obstacles to the implementation of these advanced technologies and the future trends they portend. The research results of this paper not only bring novel insights and concepts to the field of architectural creativity, but also contribute substantial insights to the continuous evolution and optimization of related technologies.

Keywords: Extended Reality; Interactive Systems; Architectural Design; Virtual Reality; Augmented Reality; Hybrid Design.

1. The Definition and Development of Extended Reality (XR)

The concept of XR (eXtended Reality) encompasses multiple technology domains such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). The essence of such technologies is to create innovative audio-visual and perceptual experiences through the integration of digital information and the physical world. Virtual reality (VR) uses computer technology to build a full range of simulated three-dimensional digital Spaces, allowing individuals to immerse themselves in this completely fictional dimension and interact with the virtual realm with the help of Head-Mounted displays (HMD) and manipulative tools (such as joysticks, tactile gloves, etc.). Augmented reality (AR) enhances visual perception by embedding digital information on the actual scene [1], and viewers can gain insight into the virtual content superimposed with reality through transparent displays such as AR glasses or handheld devices such as smartphones. Mixed reality (MR) integrates the characteristics of VR and AR to further unlock more diverse interactive scenes, making the boundary between the virtual and the real world blurred, allowing users to perceive the real world objects in the virtual context, and also integrate with the virtual elements in the physical space, switching smoothly between the two without obvious sense of separation.

XR technology has penetrated into many fields such as education and training, health care, industrial production and leisure and entertainment, and has shaped profound changes. In the realm of architectural planning, VR technology plays a crucial role, allowing designers to build realistic architectural simulation models that allow end users and project stakeholders to experience design ideas in a realistic virtual space, further enhancing the flow of consensus and improving customer satisfaction[2]. In design verification, the use of the

building is simulated in the virtual environment to identify potential problems in advance and make adjustments to reduce rework in actual construction. In the field investigation, through AR technology, designers can view the comparison between the building model and the actual environment in real time at the construction site, which is easy to find problems and optimize the design. In construction management, AR technology can be used for construction guidance to provide detailed construction guidelines and progress information to improve construction efficiency and quality. XR technology has penetrated into many fields such as education and training, health care, industrial production and leisure and entertainment, and has shaped profound changes. In the realm of architectural planning, VR technology plays a crucial role, allowing designers to build realistic architectural simulation models that allow end users and project stakeholders to experience design ideas in a realistic virtual space, further enhancing the flow of consensus and improving customer satisfaction.

2. Application of Interactive System in Architectural Design

2.1. Definition and Classification of Interactive Systems

Interactive system refers to a computer system capable of two-way communication with users, and through various input and output devices, users can interact with the system naturally and intuitively [3]. Interactive solutions in the field of architecture can be broadly classified into four categories. Haptic feedback technology such as touch screen, body language analysis technology, verbal command control technology, and visual gaze tracking technology. Touch screen technology, in particular, relies on the user's direct contact with the display panel to elicit an immediate response.

Gesture recognition technology uses image-capturing devices such as cameras to interpret and transform human gestures into digital commands. Voice control technology collects people's voice signals through microphones to further achieve voice-controlled interaction. Eye tracking technology, which monitors the movement of human eyes through camera equipment and takes visual navigation as the target, provides a new way of control.

2.2. The Concrete Application and Case Analysis of Interactive System in Architectural Design

The comprehensive application of interactive systems in architectural design also shows its great potential [4]. In collaborative design, design team members can collaborate in real time through multi-person collaboration platforms, such as Revit Live and Unity Collaborate, using technologies such as touch screen, gesture recognition and voice control to improve design efficiency. Interactive systems enable design teams to communicate and collaborate more efficiently, reducing misunderstandings and rework. In customer interaction, customers can interact with the design scheme through the AR/VR display platform and use technologies such as touch screen, gesture recognition and voice control to experience the future built environment in advance, improve customer participation and satisfaction, and enhance sales effect and market competitiveness [5]. Case study: In a large commercial complex design project, the designer used touch screen and gesture recognition technology to edit the model and adjust the scheme, which improved the design efficiency. Customers experience the design solutions in advance through the AR display platform, enhancing their sense of engagement and satisfaction. Through interactive systems, communication between the design team and the client is more efficient, reducing misunderstandings and rework, and increasing project success. In a high-end residential design project, the design team used voice control technology for command execution and text input, which improved work efficiency. Sales staff show customers the decoration effect of the interior of the house through AR tablets, which enhances customers' confidence in buying. Interactive systems greatly enhance the agility and effectiveness of the design process, further optimizing customer satisfaction and business results. As can be seen from the above discussion, such interactive solutions show considerable applicability in the field of architectural planning. These advanced tools not only promote the improvement of design quality and speed, but also give users a better interactive experience, and occupy a place in the business competition. Therefore, the subsequent academic research should continuously explore the deep possibilities of such technologies to meet the current challenges and create more opportunities for innovation and transformation for the integration of architectural art and technology.

3. Overview of Transnational Commercial Disputes

3.1. XR Combined with Interactive Systems

Interactive computing platforms represent a class of computer systems that can accept and respond to direct feedback from users, and communicate seamlessly with users through a variety of sensory channels, such as touch, vision, hearing, and biometrics. In the context of architectural

planning, such interaction mechanisms can be roughly summarized as touch interface technology, hand motion recognition systems, voice-activated navigation strategies, and visual tracking methods. Specifically, touch interface technology drives an intuitive manipulation experience by using the user's touch behavior on the display. Hand motion recognition technology that relies on cameras or other detection devices to interpret and transform human gestures into digital commands. Voice-controlled navigation technology uses microphone components to pick up verbal instructions from people, further opening up the possibility of screenless, touch-free interaction. As for visual tracking technology, it monitors and insights an individual's eye movement patterns through the camera, further utilizing the control logic of vision orientation.

3.2. The Concrete Application of Interactive System in Architectural Design

The penetration of interactive technology in architectural planning is quite profound, involving concept conception to form shaping, mode construction, instruction implementation, text input and user feedback. In the sketch stage, designers often use stylus hardware such as iPad Pro and Surface Pro, and draw creative ideas directly on the LCD screen with its subtle sensing technology, which not only stimulates the intuitive drawing process, but also improves the innovation efficiency. As for the form adjustment process, design experts can implement real-time shape control and optimization of the visual interface through devices such as touch displays or touch panels, ensuring the precision and agility of the design, and enhancing the presentation of visual aesthetic. In the three-dimensional construction process, the use of gesture recognition tools such as Leap Motion and Kinect, designers can use air gestures to depict virtual three-dimensional models, which not only radiates the construction rate, but also ensures the intuitive operation of the simulated space. In interactive control, users can navigate, select and operate through gestures in the virtual environment, which makes user interaction in the virtual environment more natural and intuitive, and improves user experience and participation. Voice control technology In command execution, designers can use smart speakers, voice assistants and other devices to quickly perform complex operations through voice commands, such as saving files, switching views, etc., providing a convenient operation mode, reducing the complexity of manual operation, and improving work efficiency. In text input, designers can quickly generate text, such as design documents and reports, through speech recognition software, which significantly improves the speed and accuracy of text input and reduces the work burden of designers. In the user feedback, eye tracking technology captures the user's eye movement through the eye tracker, understands the user's concerns and interest points in the design, provides objective user feedback, helps the designer optimize the design scheme and improves user satisfaction. In interactive control, users can carry out simple interactive operations through the AR/VR headset with integrated eye-tracking function, such as selecting menu items, scrolling pages, etc., providing a more natural and intuitive way of interaction and improving user experience. The case study shows that in a large commercial complex design project, the designer used touch screen and gesture recognition technology to edit the model and adjust the scheme, which improved the design efficiency. Customers experience the

design solutions in advance through the AR display platform, enhancing their sense of engagement and satisfaction. Through interactive systems, communication between the design team and the client is more efficient, reducing misunderstandings and rework, and increasing project success. In a high-end residential design project, the design team used voice control technology for command execution and text input, which improved work efficiency. Sales staff show customers the decoration effect of the interior of the house through AR tablets, which enhances customers' confidence in buying. Interactive systems bring greater agility and energy efficiency to the design process, further improving customer satisfaction and business results. From the above analysis, it can be inferred that the application potential of such systems in architectural planning is considerable. These innovative tools not only optimize the level of creation and execution, but also enhance the end-user experience and establish a competitive advantage in the business sector.

4. A New Path of Hybrid Design for Future Architectural Design

4.1. The Concept and Significance of Hybrid Design

Convergent design represents a clever convergence of extended reality (XR) technology and interactive interfaces, resulting in an innovative design strategy and process. Such methodologies cleverly maximize the immersive experience and enhanced perception of XR technology, while using the intuition and affinity of interactive systems to inject more convenient, agile and human-centered tools into the field of architectural design. Thanks to virtual reality (VR) technology, designers can implement no-dead ideas and verification in the holographic simulation space, further identify potential obstacles in advance and make appropriate corrections, and further avoid the appearance of repetitive processes during the physical construction process. At the same time, with multiple interaction modules such as gesture recognition, touch screen and voice command, designers can immediately modify the three-dimensional model and optimize the concept, improving the blueprint accuracy and engineering speed. By coordinating multiple interaction means, the communication between designers and virtual space is seamless, which greatly enriches the breadth and originality of architectural creativity.

4.2. The Application Prospect of Mixed Design in Architectural Design

The application potential of hybrid design strategy in the field of architectural planning is far-reaching. It plays a significant role in improving design quality and efficiency, and designers benefit from VR technology to implement detailed conception and verification in a full-dimensional virtual space, further identify and solve potential design problems in a timely manner, and further avoid redundant labor before actual construction. With the integration of multiple interactive systems such as gesture recognition, touch panels, and voice-activated devices, modeling revisions and solution optimization can be done in real time, ensuring design accuracy and productivity growth. The ingenious integration of various interactive means enables creatives to start a dialogue with the virtual simulation space more instinctively, which greatly strengthens the flexibility and innovation of the design. As for the level of optimizing user

experience, the advanced technologies of VR and AR enable the solution experients to preview the concept in simulated reality, and enhance the sense of integration and identification of the design of the participants, just as consumers wear VR headsets to immerse themselves in the virtual space to travel through various Settings, experience and evaluate the design response of each department. Through the interactive system, customers can adjust the design scheme in real time and achieve personalized customization. For example, customers can select different finishing styles and materials through the touch screen to see the results in real time. With MR Technology, designers and customers can collaborate remotely in real time, improving communication efficiency. For example, designers and customers can discuss and modify in the same virtual environment through HoloLens 2. In terms of optimizing project management, through AR technology, construction personnel can view building models and construction guides in real time at the construction site to ensure the accuracy and progress of construction. Combined with Internet of Things (IoT) technology, sensors can be installed on the construction site to monitor progress and quality in real time via AR devices. For example, sensor data can be viewed through AR glasses to detect and resolve problems in a timely manner. With MR Technology, the design team, the construction team and the client can collaborate with multiple teams to improve the efficiency and accuracy of project management. For example, design teams can share the same virtual environment with HoloLens 2 for real-time discussions and modifications.

Case study: In a large commercial complex design project, the designer used Oculus Quest 2 to create a complete virtual model, and customers walked through the virtual environment through touch screen and gesture recognition technology to experience the design effects of different areas. At the construction site, engineers use Microsoft HoloLens 2 to see how the building model compares to the actual environment in real time to ensure the accuracy and progress of construction. The design team uses touch screen and gesture recognition technology for model editing and scheme adjustment to improve design efficiency. Through VR displays, customers are able to intuitively understand the design intent, reducing communication costs. The application of AR technology enables the design team to find and solve problems in time, and improves the design quality. Interactive systems make the design process more flexible and efficient, increasing user participation and satisfaction. In a high-end residential design project, the designer used HTC Vive to create multiple designs, and the owner experienced different decoration styles and layouts in a virtual environment through touch screen and gesture recognition technology. In the sales center, the sales staff used iPad and ARKit to show the interior decoration effect of the house to the customer, which enhanced the customer's purchase confidence. The design team used voice control and gesture recognition technology to discuss and modify the scheme, which improved the efficiency of collaboration. Through AR display, customers can more intuitively understand the actual situation of the house, improving the success rate of sales. The application of VR technology allows customers to experience the future living environment in advance, enhancing customer satisfaction. The interactive system enables the design team to quickly adjust the scheme and improve the design efficiency. Through the above analysis, it can be seen that mixed design has broad application prospects in architectural

design. These technologies can not only significantly improve design quality and efficiency, but also enhance user experience and optimize project management. Future research should continue to explore the potential of these technologies to address existing issues and bring more innovation and change to the architectural design industry.

5. Challenges and Prospects

XR technology and interactive systems face several challenges in architectural design, mainly including high technology cost, poor user adaptability, limited technology popularity and equipment maintenance difficulties. The solution includes gradual promotion and training, selection of cost-effective equipment and technical solutions, as well as financial support and subsidies from government and industry organizations. Poor user adaptability shows that some users are not familiar with XR technology and interactive system. To address this problem, our proposed approach focuses on implementing intuitive and practical on-site presentations and educational training that create a self-explanatory interface and a smooth flow of operations, accompanied by exhaustive user guides and Internet-based coaching materials. Bottlenecks in technology adoption often stem from a lack of awareness, understanding and even confidence among many end users and business entities. The solution is to increase awareness and promotion. Equipment maintenance difficulties are manifested as XR equipment and interactive system need regular maintenance and update, the solution is to establish a special technical support team, responsible for the daily maintenance and troubleshooting of equipment, regular equipment inspection and update, establish long-term cooperation with equipment suppliers, access to technical support and services. Despite the challenges, XR technology and interactive systems have great prospects for development in architectural design. In the field of technology integration, with the continuous evolution of technology evolution, the integration of XR technology and interactive system tends to be more refined, and can further generate more three-dimensional and instinctive interactive feelings. The integration of artificial intelligence (AI) makes intelligent design and automated optimization possible, significantly improving the intelligent dimension of design. In terms of application and promotion, the application of XR technology and interactive interface in architectural art creation is becoming more and more popular throughout the whole process of building life cycle. As for the establishment of standardization and standardization, it is essential to establish uniform technical benchmarks and procedures, which can boost the overall performance of the industry in all aspects. In addition, promoting cross-border collaboration between architectural art and computer science, psychology, social science and other fields is a key driving force to stimulate relevant technological innovation. Given the increasing maturity and development of XR technology and interactive tools, a deeper exploration of the potential value of these

cutting-edge technologies will be the top priority of future research. In this context, the future architectural planning may deeply integrate the principle of ecological friendliness. Through XR technology and interactive solutions, it is expected to improve design strategies through virtual presentation and simulation experiments, avoid unnecessary consumption of resources, reduce adverse impact on the environment, and especially reduce the abuse of material resources and ecological burden.

6. Conclusion

Chapter conclusion.

Through theoretical analysis, case study and experimental design, this paper systematically discusses the application and influence of Extended reality (XR) technology and interactive system in architectural design. Empirical evidence shows that Extended reality (XR) technology and interactive interfaces show clear advantages in improving design quality and performance, enhancing user experience, and improving project control. As XR technologies and interactive interfaces continue to evolve and improve, they herald an increasingly critical function in the field of architectural planning. Future inquiry needs to be tenacious in exploring the potential benefits of such technologies, addressing existing challenges, and creating a revolutionary transformation and upgrade for the field of architectural planning. This research not only contributes new insights and ideas to the innovative conception of architectural art, but also injects a different perspective and thinking source for the technological innovation in this field, and further plays a valuable guiding significance for the perfection and deepening of relevant technologies. Through these ongoing explorations, it is reasonable to expect that future building planning processes will be smoother, smarter and more user-friendly.

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