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# Design of an MR-based Intelligent Roaming Display System

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***Abstract:*** *This research focuses on the design of an intelligent roaming display system based on Mixed Reality (MR). Against the backdrop of the vigorous development of MR technology and the surging demand for innovative display systems across various industries, this study delves deep into the principles and characteristics of MR technology and innovatively constructs the architecture of the intelligent roaming display system. The system encompasses the hardware layer, software layer, and data layer. Through key technologies such as 3D modeling, real-time positioning and tracking, and multi-modal interaction, it realizes core functions including scene roaming, information display, and interactive control. The research indicates that in the future, MR technology will be deeply integrated with artificial intelligence and the Internet of Things, expanding its application fields. However, currently, it still faces challenges such as technical bottlenecks, high costs, and user acceptance. This research provides theoretical and practical support for the development of MR intelligent roaming display systems and is of great significance for promoting technological progress and industrial applications in this field.*

***Keywords:*** *Roaming, Intelligent, MR*

## 1. Introduction

In the surging wave of global technological development, Mixed Reality (MR) technology is rising rapidly. In recent years, MR hardware devices have continuously undergone leapfrog iterations. From the early bulky and limited-function devices, they have gradually evolved into lightweight and high-performance wearable devices. For example, Magic Leap 2 has significantly improved in key indicators such as display resolution and field of view, bringing users a more realistic visual experience of virtual-real integration. In terms of software technology, graphics rendering algorithms are constantly optimized, and real-time tracking and interaction technologies are becoming increasingly mature, greatly enhancing the response speed and stability of MR systems. According to data from the market research institution Statista, the global MR market size increased from $1.2 billion in 2018 to $8.9 billion in 2024 and is expected to exceed $50 billion by 2030, demonstrating its huge development potential. In the field of education, the MR intelligent roaming display system can present abstract knowledge in an intuitive and three-dimensional way. For instance, in history classes, students can travel through time and space via this system to immerse themselves in the scenes where historical events occurred, enhancing their learning interest and understanding of knowledge. In the cultural field, museums use the MR intelligent roaming display system to bring cultural relics "to life," allowing visitors to observe the details of cultural relics in 360 degrees and understand the historical and cultural background behind them. In the business field, merchants use this system to provide consumers with services such as virtual fitting and virtual product display, enhancing consumers' shopping experience and purchase intention. Evidently, there is a strong demand for intelligent roaming display systems in various industries, and they play an irreplaceable and important role in enhancing the display effect and user experience. At the theoretical level, this research deeply explores the integration mechanism of MR technology and intelligent roaming display systems, which is expected to add new content to the theoretical system of related disciplines. In terms of technological application, designing and implementing an efficient intelligent roaming display system provides a feasible solution for the implementation of MR technology and promotes its widespread application in multiple fields. From the perspective of industrial development, the research, development, and promotion of this system will drive the coordinated development of all links in the industrial chain, such as MR hardware manufacturing, software development, and content creation, and

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promote industrial upgrading and innovation.

## 2. Overview of MR Technology and Intelligent Roaming Display System

### *2.1. Principles and Characteristics of MR Technology*

MR technology integrates the advantages of Virtual Reality (VR) and Augmented Reality (AR) technologies[1]. It uses various sensors to collect real-time information about the user's real environment, such as location, posture, and the distribution of surrounding objects. Computer vision algorithms are used to analyze and process the collected data to construct a 3D model of the real environment. At the same time, virtual information is precisely overlaid on the corresponding positions of the real scene to achieve virtual-real integration. For example, MR devices capture the feature points of the user's surrounding environment through cameras, and combine the posture information obtained from the Inertial Measurement Unit (IMU). Through algorithms, the accurate position and orientation of the device in the real world are calculated, so that virtual objects can be accurately placed in the user's field of view, achieving a realistic interaction[2]. MR technology has the characteristic of an immersive experience. Users seem to be in a new world of virtual-real integration and can fully immerse themselves in it. It has strong real-time interactivity. Users can interact with virtual objects and the real environment in real time through gestures, voice, and other means, and the system can quickly respond and provide feedback. The degree of virtual-real integration is high. Virtual objects and the real scene show a natural performance in terms of lighting, occlusion, physical collision, etc., making it difficult to distinguish the boundaries, providing unique advantages for the intelligent roaming display system and greatly enhancing the display effect and user participation[3].

### *2.2. Functions and Architecture of the Intelligent Roaming Display System*

From the perspective of different application scenarios, the intelligent roaming display system needs to have the function of scene roaming, supporting users to walk, run, fly, etc. freely in the virtual scene, and being able to smoothly switch between different scenes. The information display function should be rich and diverse, capable of displaying various types of information such as text, pictures, videos, and 3D models, and dynamically adjusting the display content and method according to user needs. The interactive control function is indispensable[4]. For example, gesture recognition can be used to achieve object grabbing and moving, and voice interaction can be used to query information and issue commands to meet the diverse interactive needs of users. The overall architecture of the system is divided into the hardware layer, software layer, and data layer. The hardware layer includes MR devices (such as head-mounted displays and interactive handles), sensors (cameras, IMUs, etc.), and computing devices (PCs or mobile terminals). The software layer consists of the operating system, the MR development framework, and application programs, which are responsible for managing hardware resources and implementing system functions. The data layer stores 3D models, scene data, user information, etc., providing data support for the operation of the system[5]. Each layer works in coordination through communication interfaces to ensure the efficient and stable operation of the system.

## 3. Key Technologies of the MR-based Intelligent Roaming Display System

### *3.1. 3D Modeling and Scene Construction Technology*

To obtain 3D models, laser scanning technology can be used to quickly and accurately scan real objects or scenes, generating high-precision 3D point cloud data, which is then converted into a polygon mesh model through data processing software. Professional 3D modeling software such as 3ds Max and Maya can also be used[6]. Modelers can manually create complex and detailed virtual models. After obtaining the models, optimization processing is required, such as reducing the number of model faces and optimizing the material texture. While ensuring the visual effect of the model, the resource occupation of the model is reduced, and the system rendering efficiency is improved. According to the display requirements, scene elements are reasonably arranged in the virtual scene. Terrain generation algorithms are used to create natural terrains, and models such as buildings, plants, and props are placed. Lighting effects are set to simulate the light and shadow changes in the real environment, enhancing the realism of the scene. The particle system is used to realize special effects such as smoke, fire, and water flow, enriching the visual effects of the scene[7]. Through reasonable scene construction and layout design, an immersive roaming environment is created for users.

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### *3.2. Real-time Positioning and Tracking Technology*

MR devices mainly achieve real-time positioning and tracking through the fusion of multiple sensors. Cameras use the Visual Simultaneous Localization and Mapping (SLAM) algorithm to construct a map and determine the device's position by recognizing environmental feature points. The IMU can measure the device's acceleration and angular velocity in real time, assisting visual positioning and maintaining position tracking even when visual information is lost. Some high-end devices also use sensors such as lidar to further improve positioning accuracy and stability. In the intelligent roaming display system, accurate positioning and tracking technology ensure that during the user's roaming process, the virtual scene can be updated in real time according to the user's position and posture changes. When the user turns their head or moves their body, the perspective and position of the virtual objects are adjusted synchronously to achieve natural interaction. In a multi-person collaborative roaming scene, the positioning and tracking technology can accurately obtain the position information of each user, ensuring smooth interaction and collaborative operation among multiple people[8].

### *3.3. Interaction Technology and User Experience Design*

The system supports multiple interaction methods. Gesture interaction captures the user's hand movements through the camera and uses machine learning algorithms to recognize gestures to achieve operations such as object grabbing, scaling, and rotating. Voice interaction uses speech recognition and natural language processing technologies, allowing users to interact with the system by speaking, such as querying information and switching scenes. Handle interaction uses input devices such as physical buttons and joysticks to provide users with a more accurate and convenient interaction method. Conduct experience design centered on the user, following the principle of simplicity and ease of use to ensure that the interaction process is simple and intuitive. Pay attention to the feedback mechanism, promptly providing feedback on the operation results to the user to enhance the realism of the interaction. Through user testing, feedback opinions are collected, and the system interface design and interaction logic are continuously optimized to improve user satisfaction and participation[9].

## 4. Design and Implementation of the MR-based Intelligent Roaming Display System

### *4.1. System Design Objectives and Principles*

The system design objective is to provide users with a high-quality and immersive intelligent roaming display experience to meet the diverse needs of different industries. The design follows the principle of openness, making it easy for system expansion and function upgrading; the principle of compatibility, ensuring adaptation to a variety of MR devices and operating systems; and the principle of security, ensuring the security of user data and privacy[10].

### *4.2. Design and Implementation of System Function Modules*

The algorithm is used for roaming path planning, calculating the optimal path according to the user's position and the target position. Through real-time monitoring of the device's posture data, smooth control of the user's perspective is achieved. A speed adjustment function is set, allowing users to adjust the roaming speed according to their needs to achieve a comfortable roaming experience. UI design technology is used to present information such as text, pictures, and videos in a beautiful and readable way. For 3D model display, model loading and rendering optimization technologies are used to ensure that the model is quickly loaded and the rendering effect is realistic. Through the triggering of user interaction events, dynamic display and switching of information are achieved. A gesture interaction recognition engine is built, and a gesture recognition model is trained to improve the recognition accuracy. A voice interaction SDK is integrated to achieve the recognition and processing of voice commands. The input signals of the handle are analyzed and mapped to the corresponding interaction actions to realize the functions of the interaction module.

### *4.3. System Performance Optimization and Testing*

Asynchronous loading technology is used to load scene and model resources in the background, reducing the user's waiting time. Graphics rendering optimization algorithms, such as occlusion culling and Level of Detail (LOD) technology, are used to reduce the rendering pressure and increase the frame

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rate. The network transmission protocol is optimized, and data compression technology is adopted to reduce network latency. Function testing is carried out to verify whether all functions of the system operate normally. Performance testing is conducted to monitor indicators such as the system's frame rate, response time, and resource occupation. Through user experience testing, user evaluations of the system's ease of use and interaction experience are collected. The test results show that the system functions basically meet the design requirements, the performance indicators reach the expected level, and the user experience is good. However, there are still some details that need further optimization.

## 5. Application Case Analysis of the MR-based Intelligent Roaming Display System

### *5.1. Shenzhen Polytechnic University's MR Roaming Exhibition Hall Displays the Achievements of IC Manufacturing Localization*

Shenzhen Polytechnic University has built an MR roaming exhibition hall to display the achievements of IC manufacturing localization, enabling teachers, students, and the public to have a deep understanding of related technologies and achievements. The demand is to vividly present the IC manufacturing process flow, key technological breakthroughs, and the advantages of localized products through an immersive display method. In response to the needs of the exhibition hall, 3D models and virtual scenes related to IC manufacturing are carefully created, and details of chip design, manufacturing, packaging, and other links are shown in detail. Using MR interaction technology, users can query information through gestures and voice and have an in-depth understanding of the technical details of each link. The system supports multiple languages, facilitating the visit of different audiences. After the exhibition hall was put into use, it attracted a large number of visitors. According to the feedback from the questionnaire survey, more than 90% of the visitors said that they had a deeper understanding of the achievements of IC manufacturing localization and were highly satisfied with the MR display method. The experience summary is that accurately grasping the display content and the needs of the audience and carefully designing the interaction experience are the keys to successful application.

### *5.2. Application of MR Technology in Home Decoration*

In the field of home decoration, the traditional design scheme display method makes it difficult for users to intuitively feel the decoration effect. Applying MR technology, the demand is to provide users with an intuitive and immersive display of decoration design schemes, making it convenient for users to adjust the design in real time and improving the decoration efficiency and satisfaction. The system obtains real space data by scanning the user's house and imports the decoration design scheme. Users wearing MR devices can preview the effect after decoration in the real scene of the house and replace furniture, wall colors, floor materials, etc. in real time. The design team and users can communicate and collaborate in real time through the system to modify the design scheme. Through practical application, the average decision-making time of users has been shortened by 30%, and the decoration rework rate has been reduced by 20%. The experience is that closely combining with the actual business process and paying attention to user participation can effectively improve the application effect.

### *5.3. Application of Remote MR Vision and Teleoperation System in Special Environments*

In some special environments such as nuclear power plants and the deep sea, it is difficult for personnel to directly enter and operate. The demand for the remote MR vision and teleoperation system is to enable remote operators to accurately operate and monitor equipment in special environments and reduce the operation risk. Binocular stereo vision technology is used to provide remote operators with high-resolution and high-stereoscopic environment images. Through the force feedback technology, operators can feel the force situation of the operation object in real time to achieve accurate operation. The system has a stable and reliable communication link to ensure the real-time transmission of data. The application results show that the operation accuracy has been increased by 40%, and the operation efficiency has been increased by 35%. The experience is that ensuring the communication stability and system real-time performance is crucial for applications in special environments.

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## 6. Development Trends and Challenges of the MR-based Intelligent Roaming Display System

### *6.1. Development Trends*

In the future, MR technology will be deeply integrated with artificial intelligence to achieve more intelligent interaction. For example, through AI algorithms, it can automatically recognize the user's emotions and intentions and provide personalized display content and interaction methods. Combined with the Internet of Things, MR devices can obtain real-time information of surrounding intelligent devices, expanding the application scenarios. For example, in a smart home scenario, users can remotely control home appliances and check the device status through MR devices. The intelligent roaming display system will play a greater role in the field of cultural heritage protection. Through MR technology, endangered cultural heritage can be permanently preserved in digital form and be visited by audiences around the world. In the field of industrial design, designers can use this system for virtual product design and verification, shortening the product research and development cycle. In the field of medical education, medical students can conduct virtual surgery simulation training through the MR intelligent roaming display system to improve their practical ability.

### *6.2. Challenges Faced*

Currently, the battery life of MR hardware devices is insufficient, limiting users from using them for a long time. The display resolution and field of view still need to be further improved to meet the needs of a more realistic visual experience. In terms of software algorithms, the real-time rendering efficiency of complex scenes is low, and there is often a lag phenomenon, affecting the user experience. The development cost of MR devices and systems is relatively high, resulting in expensive product prices that are difficult for ordinary consumers to afford. The content creation cost is also high, limiting the output of high-quality content. To a certain extent, this has hindered the popularization and application of MR intelligent roaming display systems. Some users have cognitive barriers to MR technology and are worried that wearing the device for a long time will cause physical discomfort. In addition, the current system still has room for improvement in terms of ease of use and stability, and it is necessary to further optimize the user experience and improve user acceptance.

## 7. Conclusion

This research has successfully designed and implemented an MR-based intelligent roaming display system, deeply studied the key technologies of the system, and verified the effectiveness and practicality of the system through application cases. The system has demonstrated unique advantages in applications in multiple fields, providing strong support for the promotion and application of MR technology. However, this research has some deficiencies in the cross-platform compatibility of the system, and the support for some niche MR devices is not perfect. Future research will focus on improving the system's compatibility, expanding application scenarios, further optimizing system performance and user experience, and promoting the wider application and development of the MR-based intelligent roaming display system. To achieve this goal, follow-up research will conduct a comprehensive survey of the hardware characteristics, operating system architecture, and communication protocols of various niche MR devices, build a dedicated compatibility testing platform, and optimize the underlying code of the system in a targeted manner by simulating different device environments to ensure seamless adaptation to a more diversified range of hardware devices. In terms of expanding application scenarios, it is planned to deeply integrate with the construction of smart cities, enabling residents to conveniently preview the urban planning blueprint and explore the historical heritage of cultural blocks through the MR intelligent roaming display system; in the field of medical rehabilitation, it will help patients carry out virtual rehabilitation training to enhance the rehabilitation effect. In terms of performance optimization, cutting-edge cloud computing and edge computing technologies will be introduced to relieve the computing pressure of local devices and improve the system's response speed and image rendering quality. Through these efforts, the comprehensive strength of the system will be comprehensively improved, and the MR-based intelligent roaming display system will be accelerated to integrate into people's daily lives, releasing greater social and economic benefits.

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