Characteristics of Mixed Reality Technology and Its Application in Engineering Fields

Jiaqi Liu*

Faculty of Architecture, Civil and Transportation Engineering, Beijing University of Technology, Beijing, China

*Corresponding author: olivialiu@emails.bjut.edu.cn

Abstract. Mixed reality, or MR, is a technology that incorporates information from real scenes in a virtual environment, allowing the actual and virtual worlds to be linked to enhance the realism of the user experience. With the rapid development of the 5G network and communication technology, MR technology has been used on a larger scale in every industry in the future. This study analyzes its use in engineering and non-engineering domains, discussing its benefits and drawbacks. MR can be used for data sharing and efficient communication, assisting workers in understanding and guiding their operation, and facilitating project management. However, its disadvantages include unreal images, delayed tracking, restricted condition for the environment, unsatisfactory user experience, and high costs. In non-engineering fields, MR is mainly applied to simulation, real-time interaction and so on in the military, medical science and education fields. The application of MR technology in engineering fields is mainly about construction, disaster management, and prevention. It enhances the work efficiency for construction by allowing 3D visualization of concealed or complex structure, and timely annotation. It eliminates risks for disaster management and prevention by conducting simulated drills, and optimizing escape routines.

Keywords: mixed reality; application; engineering.

1. Introduction

Mixed reality (MR) technology involves many emerging technologies and tools such as 3D modeling, motion capture tracking, gesture control, sensor intelligence interaction, and multimedia fusion, which are inseparable from the technological development of the computer industry and the improvement of its various mobile devices' performance. Over the past two decades, MR has achieved great feasibility breakthroughs and is developing rapidly. However, its current application is still limited and is still in the preliminary exploration stage in the engineering field. Although this technology can profoundly improve the degree of informationization in the field of engineering and non-engineering with its outstanding advantages, there is still a long way to go before MR technology is widely available.

Therefore, this study focuses on MR technology, analyzes its application in engineering and non-engineering fields, and discusses its advantages and problems.

2. Advantages and disadvantages of MR technology

2.1. MR introduction

MR technology is based on virtual reality (VR) and augmented reality (AR). VR technology uses computers to create a simulated three-dimensional environment that relies on professional wearable devices to achieve sensory simulation of sight, sound, and touch, allowing users to be completely in the virtual world and have an immersive experience. AR technology, on the other hand, superimposes virtual digital information on top of the real world, and in the user's field of vision, the real world is seen to be added with information in the form of text, pictures, etc. For example, Google Glass, launched by Google in 2012, is capable of fulfilling many functions such as voice-activated photography, video calling, processing information, and email communication. Many mobile

applications support AR, most typically mapping applications that superimpose information such as icons indicating routes and distances to destinations on a realistic live view of the road.

Paul Milgram and Fumio Kishino of the Department of Industrial Engineering at the University of Toronto first defined MR as the new concept of "reality-virtual continuum" in 1993 [1]. The function of MR is positioned between VR and AR, combining the advantages of VR and AR, based on which human-computer interaction and multi-player collaborative operation mode have been added [2]. MR technology realizes the interaction between users and the virtual world. It introduces the real scene environment information into the virtual scene environment, which can build an information loop between users, the virtual world and the real world, and realize the real-time feedback of user information to achieve a better realistic interaction experience [3]. It can also be stated that MR pursues higher fidelity based on AR, and the recognition of the environment is not simply superimposed on the virtual image in the camera's field of view but anchors the computer-generated image to a point in the real world [4].

2.2. Advantages of MR technology

2.2.1 Data sharing and efficient communication

The intellectual achievements of designers from various departments are gathered in the consolidated database, and each component is deeply connected to serve the field technicians, so that the technical level of engineers reaches an unprecedented level since each operator has the full information resources of the whole project and can undertake multiple tasks, in that way the effectiveness of the corporation is significantly improved. It means that MR technology realizes the integration and sharing of information to maximize assistance for the engineering process.

In addition, MR technology supports off-site multi-person collaborative discussions, which facilitates timely communication with experts from various industries in the face of unexpected problems.

2.2.2 Easy to understand and guide operation

MR technology can enhance the understanding of complex structures and engineering details more intuitively and understandably, and the visualization of MR makes the presentation of virtual data more straightforward, moving from two-dimensional display to 3D holographic projection, providing a novel and productive way to present information to all the participants in an engineering project. For example, MR technology is utilized in the construction case of the Hengqin International Finance Center Building, where workers can use gestures or buttons to simulate the installation process in glasses. Each animation shows the key information and precautions of the process in full to assist on-site construction. In addition, if the engineers encounter unexpected difficulties during on-site implementation, they can get remote expert guidance through MR equipment to help address the problems.

2.2.3 Facilitate project management

MR brings data and informationization to the whole life cycle of a building. Problems found anywhere at any time during construction or operation and maintenance could be synchronized in the cloud database, giving project managers a holistic view of the project. Moreover, experts and supervisors can be fully informed of the site situation without having to be on site.

2.3. Current problems of MR technology

In terms of the realism of the output image, due to the limitation of image rendering technology, the portrayal of factors such as light, texture, and material of virtual objects, and the processing of relative position relationship between objects are not authentic enough, which affects the user's judgment of depth, orientation, and shading relationship perception; the image has distortion so that the user experience is not satisfactory. At the same time, the problems of too small a field of view and low resolution in MR are not fully resolved due to hardware limitations [5].

Regarding tracking problems, real-time positioning can be delayed, especially when the viewpoint is rotated drastically, and the continuity of spatial changes is not capable of articulation.

In addition, the conditions of the environment can be rigorously restricted. For instance, its high requirements for ambient light. The too bright or too dark environment could make the user experience degraded, and the construction site is difficult to artificially control the surrounding light, making MR equipment lose spatial positioning or render the human eye unable to identify objects clearly. It has become a major obstacle to the application of MR technology in the field of engineering.

From the operators' perspective, for one, many head-mounted displays are prone to dizziness and fatigue which are not ideal for long-term employment; for another, this emerging technology could occupy them for extended periods of time to adapt and learn.

Lastly, from the perspective of the technology introducers and equipment purchasers, the current price of MR equipment is rather exorbitant. Taking Hololens2 as an example, each is sold at $3,500. Therefore, it is indispensable to let them see the long-term, sustainable development value of buying and putting a large number of them into use.

3. Application of MR technology

3.1. Application in non-engineering fields

3.1.1 Application in Military

The application of MR in the military field includes conducting military training, simulating equipment maintenance and combat command and control, etc. MR technology allows soldiers to have an immersive combat experience during regular training, effectively improving training quality and efficiency, saving costs, and ensuring safety. Auxiliary maintenance systems with integrated computer management software work with MR equipment to provide users with queryable information resources while in operation, or synchronize historical record data of a certain equipment to guide users to smoothly-going maintenance efficiently. The combat command and control system gives the militarist a strategic view of the whole picture, visualizing all combat information in three dimensions, which can facilitate the militarist to adopt more judicious decisions [5].

3.1.2 Application in medical science

In 1994, Andrei State and others at the University of North Carolina at Chapel Hill developed a medical AR application to display the fetus on a pregnant woman's body in real-time. Subsequently, MR has been gradually developed and integrated into the field. To date, MR technology can be applied to preoperative communication between doctors and patients to present the surgical planning and design visually; intraoperative real-time all-around navigation to improve surgical precision and safety; to gain a clearer observation of the location of the lesion and to expand the field of view during a precise surgery; and for infectious diseases, to reduce the risk of infection by presenting real-time images in 3D to restore the live reality and guide clinicians [6].

3.1.3 Application in education

MR technology is integrated into the multimodal and human-computer collaboration teaching process, which is based on theories of mind flow + immersion, context + embodied cognition, aiming to improve teaching effectiveness and comprehensively promote the development of learners. In particular, it supports STEAM education, a product of the deep integration of five disciplines: science (S), technology (T), engineering (E), art (A), and mathematics (M), which is interdisciplinary, collaborative, experiential, and technological, and requires the cooperation of MR devices to develop students' creative imagination, collaborative investigations, and problem-solving skills [7].

3.2. Application of MR technology in the engineering field

3.2.1 Applications in building construction and management

In 2016-2017, the Zhaojun Museum, constructed by China Construction First Group, Construction & Development, Co, Ltd., was the first application of MR technology in China's engineering field [8]. Subsequently, the construction of the Hengqin International Financial Center Building in 2018 applied MR specifically to issues such as virtual pipeline inspection, virtual concealed acceptance inspection, virtual operation and maintenance, positioning function, generality system, and collaborative working mode [9].

The Ecole Nationale Supérieure des Techniques d'Ingénieurs (France) has proposed MR applications based on BIM data and drone video that enables off-site construction supervision. This technology overlays two data sources, with experts marking differences between what is planned in the BIM and what has been built, through the drone view. These can then be transferred to the BIM model for amendment [10].

Moore et al. summarize the case of applying VR-MR avoidance systems in construction and mention that within the architecture, engineering, and construction (AEC) field, VR-MR systems have been developed to help professionals make more intelligent decisions and to enhance interdisciplinary interoperability and collaboration. For example, it allows users to see the location of columns behind finished walls or to reinforce steel within columns [11].

3.2.2 Applications in electricity construction

The main obstacle to the construction of power systems is the complexity and concealment of lines and equipment, and the technical advantages of MR technology for real-time interaction and visualization can be the solution to these difficulties.

Zhang et al. have incorporated MR technology in the distribution network operation and maintenance scenario, and the main functions developed are remote collaboration and inspection assistance [12]. In order to solve the problem that personnel may encounter during daily inspection and accident handling, an MR remote expert system is introduced. The remote expert system supports a collaborative environment with two-way voice communication and video transmission, and the expert side can view the front-line personnel's work scenes in real time, make real-time annotations on the work scenes, and transmit them to the front-line work side.

In the inspection process, MR equipment provides cloud database support, which allows workers to pull out the inspection record sheet on site and update real-time data synchronously. In this way, when a worker discovers a problem and reports it in time, multiple related parties can receive a notification simultaneously, which helps to arrange and coordinate the subsequent works.

Wang has suggested that the modern power system is constantly updated, which means higher workers' professionalism is required [13]. With the introduction of MR technology, workers can not only learn to perceive the spatial structure of the power system clearly and intuitively, but can also label the information on the virtual structure from any perspective. Later, they can practice disassembling and assembling the equipment compromising the electric power system in simulation, and become more familiar with the physical structure and working principle of various equipment. The workers can continuously practice as many times as they need, so that they can master the safety rules and regulations more solidly by combining theory with practice, become familiar with the operation means, improve the proficiency of operation, reduce the difficulty of electric power system overhaul and maintenance, and improve working efficiency.

3.2.3 Applications in flood prevention

MR technology can visualize and demonstrate the entire flood damage, and provide an immersive 3D interactive operating system that allows users to experience as if they were authentically present at the scene. At this point, the workers should be clear about how to complete their work appropriately under the sudden and severe circumstances of a flood disaster. Through realistic simulation drills, workers can best gain hands-on experience and thus perform well in the real hazardous scene.

In addition to enabling staff to adapt and practice in advance, MR also plays a more macro-level role. This is mainly reflected in the fact that MR gives urban planners a more reliable basis for risk prediction and policy formulation.

An MR application study was conducted in Xiushui County, Jiangxi Province, China. Following the "prevention-oriented, prevention-rescue combination" work policy, the small watershed of Hangkoushui in Xiushui County (Xinwan Township to Shuangyan Village) was selected as the object. Yang et al. combined the reality of this small watershed with MR technology, scene fusion, and other new technical means in the Hololens application platform. The simulation environment of information fusion and interactive 3D dynamic scenery was created. The simulation of flash floods in MR and construction of the local flash flood defence system were also integrated [14].

The project connected the databases of various relevant sides, such as the topography of the place and precipitation, and applied them to the virtual scenario in order to pursue utmost realism. In fact, throughout the entire project, MR simulated the process of a local flash flood defense system in several steps such as scientific introduction, monitoring, early warning, relocation and resettlement, and disaster simulation. The main core technologies required include GPU dynamic lighting underlay, rendering pipeline mapping, transforming 3D vertex coordinates and lighting calculation, rasterization, light and shadow processing, and display layer optimization.

The operation process is achieved by gesture-driven interaction. By gesture clicking on the 3D model, it would display the special effects or disaster details of different regions, including rainfall and water level changes, water level flow potential, flow direction, and other factors affecting water level changes.

3.2.4 Applications in mining security management

The environment faced by mining engineering is largely unknown and the risk factor is relatively high. With the application of MR technology to mine security management, not only can the life safety of construction personnel be guaranteed, but also the construction efficiency of mine engineering can be enhanced, so that the production effectiveness of enterprises can be maximized. MR can be used to familiarize with the internal route configuration of the mine, professional equipment operation training, safety skills training, disaster scenario reenactment, self-help escape simulation, etc. With high-security features, strong interactivity and repeatable rehearsal, it is applicable for training workers before actual operation.

Based on the mine simulation system, through a number of monitoring and control systems such as safety monitoring and surveillance, underground personnel locating, automation system and various production dynamics, the internal and external corporatization information platform is built to ensure the safe and efficient exploitation of the mine. At the same time, it provides intelligent decision support for mine scheduling and command.

Taking Yanqianshan mine as the study area, Jing et al. established an escape path planning system based on the innovatively-used MR technology. In fact, after achieving the synchronization of real-time updates of underground space information, there could also be very great use, in addition to the planning of the route, but also to enable the deployment of personnel, and quality supervision [15].

4. Conclusion

This study focuses on MR technology, discusses its advantages and problems, and analyzes its application in non-engineering and engineering fields.

MR establishes an in-depth data connection with real-time updates, interactive connection for efficient information interchange; it is clear and easy to understand and guide the work due to holographic 3D presentation; and it is used throughout the whole project cycle to serve project management.

MR technology's application in non-engineering fields is mainly related to military, medical science and education. In the military field, MR functions for conducting military training, simulating equipment maintenance and combat command and control. In medical science, MR functions for

consulting, navigation, precise observations and long-distance image convey beforehand. In education, it elevates teaching effectiveness through 3D visualization and interactive study mode.

MR technology's application in engineering fields is mainly about construction, disaster management, and prevention. For building construction and its management, MR enhances work efficiency by allowing 3D visualization of concealed or complex structures, timely annotation etc. For electricity construction, MR provides workers with realistic training before operation, and they can also report faults at any point, share data, and communicate with remote experts in real scene. For disaster management and prevention, examples mentioned in this study include predicting and simulating upcoming flash floods based on database for engineering reinforcement prevention and simulated drills for rescuers; monitoring construction progress in real-time for intelligent decision making to help mine workers plan escape routes. From this, MR's application in engineering is very promising and effective. This technology can greatly enhance the degree of informationization in engineering considering its outstanding advantages. There have already been some tentative attempts to apply MR technology in engineering projects, and in the future, it could certainly be put into the engineering field in a larger volume.

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