Development of Key Technologies of Virtual Reality and Augmented Reality and Their Application

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Abstract: With the rapid development of computer science and technology, the application of information technology in people's work and life has become more and more extensive and important. Information equipment's hardware and software environment has also been greatly developed, which has promoted the development, maturity, and application of many new technologies. Virtual reality and augmented reality technologies have begun to attract widespread attention from the government, the enterprise, and people from all walks of life. Focusing on the development trend of virtual reality and augmented reality technology, this paper summarizes the technical characteristics, the key technologies' development status, and the wide application of virtual reality and augmented reality. Hope to help relevant personnel refer to and borrow in the process of making decisions, development, and technological breakthroughs in technology applications through this article, to lay a more solid foundation for the continuous development and application of virtual reality and augmented reality technology.

1 INTRODUCTION

Virtual reality technology (VR for short) creates artificially constructed three-dimensional virtual environments in which users naturally interact with objects, greatly expanding the ability of humans to understand, simulate and adapt to the world. VR technology started to emerge in the 1960s and 1970s and began to take shape and develop in the 1990s, solving major or universal needs in many application areas such as simulation training, industrial design, and interactive experience (Ronald T. Azuma, 1997).

Augmented reality technology (AR for short) improves the user's awareness of the real environment through the use of computer-generated three-dimensional as well as multidimensional information. Using technologies such as visualization, optoelectronic display, and human-computer interaction to reflect the information of the virtual environment in the real world through senses, and accurately overlaying the computer-generated virtual scenes, virtual objects, or information into the real scene to achieve a seamless connection between the real world and the virtual scene. So that when the user visits the virtual world in the real scene, a real environment effect is presented to the user from the visual and tactile senses (Zhu Miaoliang, Yiao Yian, Jiang Yueliang, 2004).

AR and VR technologies can not only improve the intensity of interaction between the information environment and the real environment but can also further promote the growing demand for immersive digital applications. Therefore, to better improve the quality of the application of VR and AR-related technologies, this paper focuses on the development trend of VR and AR, reviewing the technical characteristics of VR and AR, the current state of development of key technologies, and the wide application of these technologies. It is hoped that this paper can help relevant personnel in the process of decision-making, development, and technological breakthroughs in technology applications, to lay a more solid foundation for the continuous development and application of VR and AR technology in general.

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2 VIRTUAL REALITY AND AUGMENTED REALITY

Virtual Reality was proposed by Jaron Lanier, the creator of VR, in the early 1980s. It refers to the integrated use of computer graphics systems and a variety of display and control and other interface devices, in the computer-generated, interactive three-dimensional environment to provide immersion in the technology, where the computer-generated, interactive three-dimensional environment is called the virtual environment.

The basic characteristics of VR are immersion, interaction, and conception. Compared with other computer systems, VR systems can provide real-time interactive operation, three-dimensional visual space, and a multi-channel human-computer interface. As a new type of human-computer interface, VR not only immerses participants in the virtual world generated by the computer but also provides a direct means of communication and interaction between the user and the virtual world. Using VR systems, the real world can be simulated dynamically, and the dynamic environment can respond to the user's posture, verbal commands, etc. in real time. The computer can track the user's input and modify the virtual environment obtained from the simulation promptly according to the input. so that a real-time interactive relationship between the user and the simulated environment is established to create a sense of immersion. Thus, VR technology has changed the way humans obtain information, improved the harmony between humans and machines, and made the human-computer interface more intuitive. VR technology inherits the latest technological developments such as computer graphics, simulation, artificial intelligence, sensing technology, display technology, and high-speed network transmission. Its emergence opens up a new way for human beings to understand the world.

AR is a new technology developed based on VR technology. It is a technology that uses a computer to generate additional information about the real world seen by the user for scenery enhancement or expansion. It superimposes computer-generated virtual objects, scenes, or system cues onto the real scene to “augment” reality. In an AR environment, users can see the real environment around them along with computer-generated augmented information. This augmented information can be virtual objects that coexist with the real environment in the real environment or non-geometric information about the real objects that exist. AR builds a bridge between VR and the real world (Azuma R, Baillot Y, Behringer R, et al., 2001).

AR was created with the development of VR technology, so there is a close and inseparable relationship between the two, but there are also significant differences. VR systems emphasize the complete immersion of the user's senses of sight, hearing, and touch in a virtual environment, emphasizing the immersion of the user's senses in a completely computer-generated space (Cyberspace). VR is usually done with the help of display devices that can isolate the user's vision from the environment, generally using immersive helmet displays (Jue Wang, Keith J. Bennett, 2013). In contrast, AR systems not only do not isolate the surrounding real environment but also emphasize the user's presence in the real world and strive to maintain the constancy of their sensory effects displays.

The application of AR involves how to superimpose the virtual objects generated by the computer into the video stream in real time as required by the user. In the process of placing 3D virtual objects into the user's environment, it is necessary to first determine the exact position of the virtual object in the 3D scene, and then when the camera position changes, the virtual object should be projected correctly relative to the camera. The essence of this type of problem is how to describe the motion of the camera so that the virtual object can be added to the user's environment accurately and quickly.

The development of computer vision technology has greatly promoted the application of AR, making the AR model much more flexible and realistic. AR not only inherits the advantages of VR but also has the characteristics of combining reality and reality. Compared with VR technology, AR technology brings the computer into the user's " world". Instead of immersing the user into the world of the computer. It allows the user to receive various auxiliary information from the computer about the actual objects as they interact with them.

3 KEY TECHNOLOGIES FOR VIRTUAL REALITY AND AUGMENTED REALITY

VR technology establishes an artificially constructed three-dimensional virtual environment, users interact with objects in the virtual environment naturally and influence each other, which greatly expands the human ability to understand the world, simulate and adapt to the world. VR technology has made great progress in theoretical technology and application development, and the main scientific issues include

modeling methods, performance technology, human-computer interaction, and equipment, which are three major categories.

The technology of superimposing 3D virtual objects into real-world displays is called AR. The synthesis of the real world and virtual environment reduces the workload of 3D modeling, improves user experience and credibility with the help of real scenes and objects, and promotes the further development of VR technology. AR technology is "real with virtual', the image captured by the camera truly reflects the real scene, which can reduce the modeling and rendering workload of the scene, providing a lightweight and realistic technology.

The technical characteristics of AR can be separated from the following three points: mixing virtual and real environments; real-time interaction; and three-dimensional registration.

The key technologies of VR/AR contain mainly the following :

- **Environment Modeling Technology:**

That is, the establishment of the virtual environment, the purpose is to obtain the actual three-dimensional data of a three-dimensional environment, and according to the needs of the application, use the acquired three-dimensional data to establish the corresponding virtual environment model.

At present, the study of the physical representation of virtual objects and their physical models is mainly focused on kinematics and dynamics. Physical models are available only for particle systems, spring models, smoothed particle hydrodynamics methods, and a few others. Many physical characteristics of matter (such as material characteristics), physical phenomena such as explosions and cuts, realistic representation of physical characteristics, and interaction responses of material objects such as flexible, viscous, plastic, flow, gas, and field in real-time, there are many theoretical problems. The balance between real-time and realism for specific applications is also a problem to be considered because of the huge computational effort of the physical model.

With the continuous expansion of VR application fields, virtual human manipulating entities (e.g., aircraft, vehicles, etc.) becomes an important part of VR systems, and the behavior of these intelligence makes the three I (immersion, interaction, imagination) characteristics of VR systems develop to four I, i.e. intelligence. The solution to this kind of problem depends on the development of artificial intelligence technology and human brain science.

- **Haptic Feedback Technology:**

In VR systems, users can manipulate virtual objects directly and feel the reaction force of the virtual objects, thus creating a sense of immersion.

There are still a large number of problems with the way and mechanism of force/haptic realistic perception between human and virtual objects and their devices, especially the sense of flexibility; in addition, the study of new perceptual channels, such as the sense of temperature and humidity, smell/taste, etc., is a problem area that requires multidisciplinary cross research to solve.

- **Interaction Technology:**

Human-computer interaction in VR technology goes far beyond the traditional mode of keyboard and mouse, using complex sensor devices such as digital helmets and digital gloves, as well as three-dimensional interaction technology with voice recognition and voice input technology to become an important means of human-computer interaction.

The spatial calculation of virtual scenes in head-mounted displays, including the real-time accurate tracking and positioning of the experiencer's head and position, as well as the location calculation and real-time performance of virtual objects in real space in AR head-mounted displays are issues that need further research. Related to this, virtual-real fusion is one of the basic problems of AR, including the fusion of graphic objects and video images in video-based AR display, and the fusion of graphic objects and real scenes in optical perspective-based AR display, and many problems are yet to be solved. Meanwhile, the outdoorization of optical perspective AR, including the fusion of reality and reality in large outdoor scenes, is a direction to be explored.

- **Mobile Terminal and Internet-Based VR:**

Mobile terminal and Internet-based VR have great potential for development. For the former, low computing and low storage VR technology, cloud VR technology, low latency big data transmission and new interaction are innovative technology directions. The latter requires full-screen 3D drawing, VR device access with more appropriate human-computer interaction mechanisms, and new browser standards. web VR will bring change and disruptive impact on existing browsers and mail systems, etc., and become the new entrance to the Internet.

- **System Integration Technologies:**

  Since VR systems include a large amount of perceptual information and models, system integration technologies are of top priority. These technologies include information synchronization, model calibration, data conversion, recognition, synthesis, etc.

At present, the productivity of VR content production is low because of the low automation and intelligence of tools and development platforms for VR modeling, drawing, and repair, and because VR hardware is incompatible and uses its software development kit (SDK). Improving the efficiency of 3D modeling (geometry, image, scanning, etc.) and the level of automation of cavity repair are elements that need further research, and developing standard application program interfaces and common software packages is an inevitable way to improve sharing and R&D efficiency.

4 APPLICATIONS OF VR AND AR

VR and AR technologies have seen significant developments in manufacturing applications (Dong Xiaofei, 2012).

4.1 Manufacturing

The use of remote real-time monitoring and sharing of expertise such as equipment maintenance and operation can help workers complete repairs and perform troubleshooting and maintenance of machines. VR and AR can help solve a range of problems in visualizing and guiding operations (Zhang Qiuyue, 2017). This technology can carry out operational guidance on technical support to solve equipment problems and ensure proper operation of equipment.

The intelligent management of VR and AR technologies in machinery is shown in Figure 1. The platform provides customers with a full range of services such as training, maintenance, remote assistance, evaluation, quality control, and diagnosis (Ren Fuji, Bao Yanwei, 2020).

Using VR/AR technology, companies can improve R&D efficiency, reduce production costs, shorten R&D cycles and improve product stability.

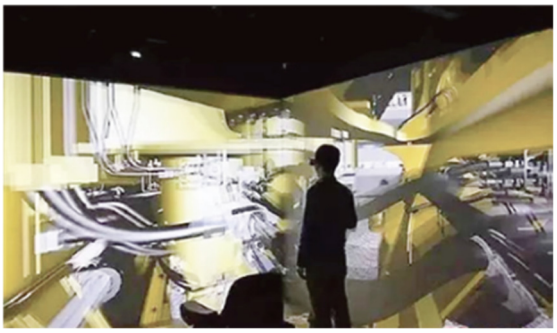

Figure 1: VR/AR machinery intelligent management platform.

4.1.1 Application for Virtual Assembly and Production Line

In machinery manufacturing, VR technology is used to establish virtual parts for assembly, users can simulate the product assembly process, check the design of the parts in the virtual assembly process, whether the assembly process produces interference situations, and the parts design drawings to modify.

VR technology applied in product production can improve design, enhance enterprise production efficiency, shorten the production cycle, and reduce production costs. The use of VR technology allows enterprises to improve market responsiveness and strengthen flexibility in production processes.

4.1.2 Application in Machinery and Equipment Maintenance

The use of AR/VR technology in machinery and equipment maintenance can improve the efficiency of maintenance. Using AR smart glasses for machinery and equipment maintenance can view the specific operation steps of equipment fault repair. At the same time, through the smart glasses communication system for maintenance operation guidance, maintenance personnel with insufficient work experience can also complete the repair and maintenance tasks with the help of the system to ensure the standardization and standardization of the operation process. AR technology combined with equipment system monitoring data analysis can discern whether the machinery and equipment are running normally, fault problem analysis, and elimination, to achieve stable use of equipment.

4.1.3 Business Marketing

Enterprises can apply VR, and AR technology to present the shape, material, parts, and internal structure of the product as well as the design principle,

working process, performance characteristics, and usage of the machinery through virtual 3D images. Using VR technology, customers understand the internal structure of the product and how to use the equipment, etc. in an all-around way. At the same time, it can also put the equipment maintenance, and fault judgment maintenance tutorial guide customers to learn to use, which can ensure the normal operation of the equipment, but also more convenient maintenance equipment, greatly increasing the customer's desire to buy.

For enterprises, VR and AR technologies can enhance customers' understanding of products and reduce the cost of equipment transfer and exhibition set-up during exhibitions and implementation sessions, as shown in Figure 2.

Figure 2: VR/AR Application in enterprise product marketing

4.2 Military

AR technology has entered the military field in many aspects of the application and began to play an important role. Countries around the world also attach great importance to the use of AR technology in the military field, in the manufacture of weapons and equipment, battlefield environment display, troop exercises and training, rear-end integrated security, and other aspects of a large number of research and exploration, and achieved a series of results, showing a broad application prospect.

4.2.1 Defense Industry Production

AR technology used in the field of the defense industry is mainly reflected in four aspects: First, it can display and share information in real-time such as physical objects, models, design drawings, etc. Using multi-channel human-machine natural interaction technology, which makes it possible for off-site, multiple people to interact in real-time, communicate and exchange design ideas, modify and improve the program. Second, the model of weapons and equipment and a variety of possible design solutions can be integrated and displayed to the user, the user can compare a variety of options through the AR system, and can directly reflect the modification to the development of the equipment model. Third, it can provide users with an advanced demonstration, allowing developers and users to simultaneously enter the virtual and real combat environment to operate the weapon system, to test the design of the weapon system, tactics, technical performance indicators, and the rationality of its operation. Fourth, the standard workflow guidelines for assembly and maintenance can be accurately displayed to the user, significantly improving the efficiency of equipment development and equipment practicality.

4.2.2 Battlefield Environment Display

AR technology is used in battlefield environment display, mainly through the integration of virtual objects in the real environment, not only can display the real battlefield scene to the troops, but also can enhance the display of the real battlefield scene by adding virtual objects to emphasize the environmental information that cannot be seen by the naked eye, as well as the hidden forces of the enemy or their side, thus truly realizing the visualization of various battlefield information. For example, using AR technology for a pilot cockpit display, on the front glass of the pilot's cockpit, or their helmet display, not only can provide navigation information to the pilot, but also can provide enhanced battlefield information including the enemy's hidden forces.

The helmet-targeting display based on AR technology can project relevant information directly onto the pilot's helmet viewfinder, providing him with a virtual picture of the helicopter's surroundings so that the combat scenes or targets can be displayed to the pilot in AR under various types of harsh geographical and meteorological conditions.

4.2.3 Operational Command and Control

AR technology is used in combat command and control, mainly in 3 aspects: First, the application of AR technology in the combat command system can enable the commander to grasp the situation of each combat unit and task force in real time, which is conducive to the commander to quickly and correctly understand the intention of superiors and make timely decisions. Second, the application of the combat command network system can enable commanders at

all levels to simultaneously watch and discuss the battlefield as well as interact with virtual scenes to achieve a high degree of sharing of information across the battlefield, which is conducive to a unified understanding and close collaboration among commanders at all levels. Third, the AR system applied to multi-user, multi-terminal collaborative work, can establish a shared, understandable virtual space for each user, and terminal, allowing each user, and terminal to share battlefield information, real-time communication, and interaction, conducive to command troops to strengthen cooperation, collaborative operations.

4.2.4 Military Exercise Training

The application of AR technology in military exercises and training helps to innovate exercise training methods and methods and increase the degree of actual combat. The application of a military training system based on AR technology can build an extremely realistic combat-oriented training environment. Trainees can see not only the real training scenes but also various combat-oriented virtual objects added to the scenes through the AR system they carry with them so that trainees can conduct immersive training and further enhance the combat-oriented level of military exercises and training (Roberts, D, et al., 2012; Sun Tong, Qu Lei, Lai Ming, 2022; Wang Minghui, Sheng Yu, Zhou Haiguang, et al., 2018).

The "AR sandbox system can visually reflect the real terrain of the battlefield so that combatants can immerse themselves in the battlefield terrain, which will have a significant impact on military training, and adversarial exercises.

Figure 3: Military Exercise Training with VR.

4.2.5 Equipment Maintenance Guarantees

AR technology used in the maintenance of weapons and equipment, by adding all kinds of maintenance support information in the actual equipment, can guide the maintenance personnel to implement maintenance by step, can pinpoint the parts that are not directly visible and visualize them, to confirm the parts to be tested and repaired or replaced, which can not only help maintenance personnel quickly familiar with and master a variety of weapons and equipment maintenance techniques, but also ensure the standardization of the entire maintenance process greatly reduce the training costs of maintenance personnel, reduces the difficulty of equipment disassembly, maintenance, and repair, and improves the efficiency of maintenance and security.

Figure 4: AR technology for equipment maintenance.

4.2.6 Military Medical Treatment

AR technology used in military medical treatment can superimpose various types of information about the sick and wounded on the body or physical mannequins of the sick and wounded, helping doctors to make surgical plans, precise positioning, and Auxiliary guidance during surgery, and simulated surgical training. For example, after a critically ill patient is put into an ambulance, it is a long journey from the ambulance to the hospital. The accompanying doctor wearing AR glasses can quickly transmit the patient's illness to the attending doctor in the hospital through the camera on it, and the attending doctor can make an emergency plan according to the situation to save lives quickly. In the ward, nurses seeking the ward through AR glasses can quickly transmit the situation of the sick and injured to the doctor in the office, and the doctor does not have to personally go to each patient's bed to check, improving medical efficiency. During surgery, it also provides a first view of the surgical process, facilitating telemedicine collaboration, prompting surgical steps, and enhancing surgical reliability by prompting attention to details of the surgical process through AR effects.

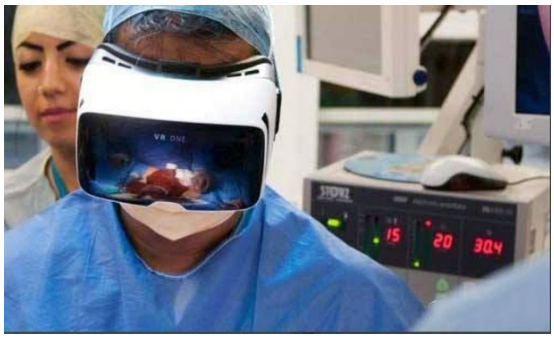

Figure 5: Military medical treatment.

4.3 Education

VR and AR technologies can be used to simulate objects, allowing learners to see virtually generated model objects in the context of a realistic environment (Shen Yang, Lu Xing, Zeng Haijun, 2020). This means of interaction based on the real world and augmented by virtual data gives educators a whole new way to express learning objects and also builds a space for learners to explore on their own in the most natural way of interaction. This is very inspiring for teaching abstract content. It is due to these features that it has great potential for development and application in the field of education (Zhou Meiyun, 2020; Liu Gengzhe, Liu Xiaowen, Gou Zhaoyuan, 2022; Buentello-Montoya D A, Lomeli-Plascencia M G, Medina-Herrera L M, 2021).

AR-based virtual learning environments are new in the field of education, where learners interact with the environment and get feedback quickly and decide what to do next based on the feedback results, establishing a link between knowledge and response. This is consistent with Piaget's vision and practice of "bringing the laboratory into the classroom" and with the constructivist learning theory that "learning is an experience of real situations".

4.3.1 Vocational Training

AR technology is widely used in the field of vocational education, providing realistic simulation opportunities for some experiments and training that are difficult or dangerous to carry out due to objective conditions. For some subjects that need to receive 3D information in the learning process, AR technology displays physical information, making it easier for learners to get three-dimensional models and create a continuous learning experience for learners.

Here is an AR application that helps engineering students improve their spatial skills. As shown in Figure 6, a book that presents a 3D model helps students complete a virtualization learning task to improve their spatial imagination skills within a short remedial course.

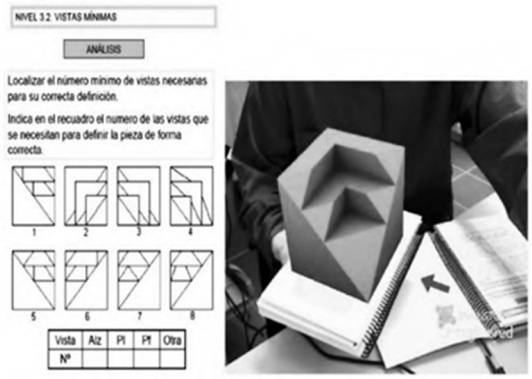

Figure 6: VR-assisted vocational training.

4.3.2 Medical Education

AR technology plays a unique role in the field of medical education, which can help medical learners establish a three-dimensional dynamic concept of the human body system, observe internal activities, and simulate surgical practices. With AR technology, it is possible to get different levels of human body structure with just a flick of the hand and observe an organ's movement individually, as shown in Figure 7. Links, videos, or models can be presented through AR technology while the learner is looking at the book to help the learner establish a physical concept of what they are learning.

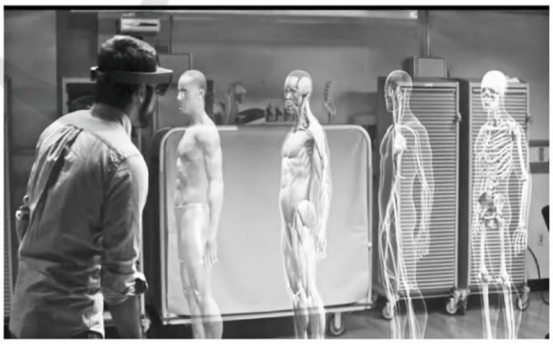

Figure 7: AR Medically Assisted Education.

4.3.3 Engineering Education

In an engineering education system for maintenance training of machines, the AR system not only displays real information and superimposed virtual information through a camera, but also shows the location of the operation in the display through a tactile pointer. Teachers and students can use this

system for experimental demonstrations or open exploration of complex task solutions, as shown in Figure 8. This system is an excellent tool for learning experiences for some complex experiments.

Figure 8: AR machine maintenance training.

4.4 Sports

VR and AR in sports, including research projects such as VR sports rooms, VR tennis, and VR cycling (Wang L P, 2022).

Sports IT-integrated theme parks can provide consumers with more diverse sports and entertainment experiences by introducing and upgrading entertainment facilities that reflect virtual and AR, and consumers get sports satisfaction through various VR experiences. In particular, the completion of various theme parks such as sports VR theme parks, virtual basketball parks (Figure 9), virtual tennis parks, virtual horseback riding arenas, etc., can provide a comprehensive experience of sports VR sports such as screen basketball, soccer, horseback riding, cycling, skiing, shooting, etc., ensuring the fun and competitive nature of sports.

VR/AR Basketball Theme Park

Figure 9: VR/AR Basketball Theme Park.

4.5 Medicine

VR and AR technologies are also used in the field of medicine, not only to provide more diversified and realistic case analysis for difficult cases that are currently rare but also to build a better virtual operating table, which can play a greater role in enhancing doctors' own surgical experience. The technology is also widely used in telemedicine collaboration and rehabilitation treatment, and has a positive impact on the development and optimization of medical treatment in China, as shown in Figure 10.

Figure 10: Telemedicine-related application.

5 CONCLUSIONS AND FURTHER DEVELOPMENT

As a novel type of human-computer interface and new technology, VR and AR are receiving a lot of attention and have already played an increasingly significant role, showing high potential for application. However, many issues still need to be addressed to realize the full potential of VR and AR in the future. For example, research on faster and more reliable real-time image generation algorithms, research on psychological, physiological, and sociological effects of VR and AR on operators, improving the convenience of VR and AR development tools, developing VR sensing devices that meet market needs, and are acceptable to the general public, creating exemplary engineering applications, etc.

VR and AR technologies provide a powerful means to expand human intelligence and will have a huge and far-reaching impact on production methods and social life. As technology continues to evolve, its content will continue to grow. And as the price of input and output devices decreases, the quality of video displays improves, and highly functional but

easy-to-use software becomes practical, the applications of VR and AR are bound to grow. the prospect of VR and AR technologies revolutionizing artificial intelligence, CAD, graphics simulation, virtual communications, remote sensing, entertainment, simulation training, and many other fields is extremely attractive.

From its creation to its development to becoming a brand-new way for human beings to expand and access the world, VR technology is rapidly entering all walks of life, showing its great technological leadership and driving force. VR is rapidly entering two major application aspects of industry sectors and popular life.

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