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REVIEW ARTICLE

AR technology in the design of oil and gas field surface engineering: Applications and prospects

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ABSTRACT

Wearable devices based on Augmented Reality (AR) technology can overlay computer-generated images into the real world, whereas simulation is applied to enable users to view the real world with an overlay of digital data. In the past 10 years, AR technology has moved from research laboratories to gradually a wide range of commercially available technologies for its use in the medical, manufacturing, industrial design, entertainment, marketing and military applications. This review includes an overview of AR wearables in the last 5 years including its development milestone and application cases, where specifically, some successful application cases and implications of AR technology in the oil and gas industry in the past five years are reviewed, with the aim of discussing the aspects of AR technology applications in the design of oil and gas field surface engineering, from station and line designs to its use in supporting construction. Since AR technology can provide real-time information, it will have a non-negligible application prospect in the whole lifecycle of oil and gas field surface engineering from design to operation and maintenance and will occupy a place in the digital transformation of the oil and gas industry.

Keywords: augmented reality; oil and gas field surface engineering; wearable devices; digital transformation

1. Introduction

The first film in the 1977 Star Wars film series, *Star Wars: A New Hope*, showed a very advanced hologram technology that appeared as a computer effect but predicted the future. 30 years later, 3R Technology (Virtual Reality, VR; Augmented Reality, AR; Mixed Reality, MR) makes the future technology shown in the *Star Wars* movie series a gradual reality and has become a hot spot in the current technology world. VR technology is a computer simulation of the virtual world, emphasizing immersion, and is now maturely used in games and film entertainment. AR technology superimposes virtual information into the real-world

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emphasizing presence and interactivity, has been gradually promoted in business and industry. MR technology as the further development of AR technology, more emphasis on the reinforcement of virtual objects in the real world, virtual objects and objects in the real world can block each other and can naturally integrate and interact with each other in real time, with a sense of real space, is currently developing and improving. Broadly speaking, AR is broader than MR, while MR is more stringent than AR. In this, MR can be regarded as a subset of AR where virtual images AR technology that seamlessly integrates the real world and AR technology is built on top of AR technology. MR technology has gradually entered the fields of medicine, entertainment, education and engineering with substantial applications. With the improvement of software and hardware involved in AR technology, the gradually mature AR technology has been used in the oil and gas industry with more and more application cases being reported in the past five years.

Cloud Computing, Mobile Internet Connectivity, artificial intelligence (AI), Big Data and Industrial Internet of Things (IIoT), represent the Fourth Industrial Revolution (4IR). With the waves brought by the global COVID-19 pandemic and low oil prices crisis, digital transformation has been proved difficult for oil companies and exploration has become an imminent way of survival. However, numerous oil companies have also begun to adopt technologies in their projects including smart pipe network, and digital twin technology[1,2]. AR technology is integrated with other technologies of the fourth industrial revolution to form a technological combination, which has begun as a technology adopted by many oil companies on the road to digitization technology to reduce costs, improve operational efficiency and improve workplace safety. In this matter, maximizing the potential of each of the technology plays an important role. Therefore, this paper reviewed the commercial development of AR technology in recent years and the successful commercialization of wearable devices in the petroleum industry. And the application prospects of AR technology in the oil and gas station design, line design and field construction were discussed, expecting to provide reference for designers who are interested in studying and using AR technology in the industry.

2. Commercial development of AR technology

The definition of AR proposed by Azuma RT[3] in 1997 is currently widely used. The widely accepted definition is that AR is a combination of virtual and real, real-time interaction, three-dimensional system with three registered characteristics. The first true computer-generated AR experiences can be traced back to the achievements of Sutherland IE, the father of computer graphics (CAD) and VR, who developed the world's first interactive graphics application at MIT in 1963[4] and created the first prototype AR system with Bob Sproull in 1968[5]. The concept of Sutherland IE has been developed quietly in the laboratories of NASA and the U.S. Air Force, representing the U.S. military and government departments and some universities, and it took decades for the computer and industry to experience the epoch-making changes brought about by its concept[6]. American scholars represented by Azuma RT have been tracking the progress of AR technology both in theory and application[3,7–9] while Chinese scholars began to track the development of AR technology in large numbers at the beginning of the 21st century[10–14]. In 1999, Kato H and Billinghurst M[15] developed an open-source AR software development toolkit; AR toolkit based on C | C++ and released it in the HIT laboratory of the University of Washington. With this tool, developers do not need to build their own tracking systems. AR applications can be built using this open source code, and many programmers have completed the creation of AR programs and applications based on this open source code. AR display devices can enable users to interact naturally with virtual reality content, while virtual content is integrated with the surrounding real world, and users can always maintain interaction with the real world. At the beginning of the

21st century, AR technology was seen in museums and theme parks. It was gradually applied in the virtual display and sports broadcast of sports competitions, and later in the field of games and live TV. With the development of the Flash, smart phones and global business marketing, AR technology has gained popularity in the 10th year of the 21st century. In just two years from 2015 to 2017, from Microsoft, Amazon, Apple, Google and other established technology companies to AR Start-ups, have sprung up new products in the industry.

In January 2015, Microsoft released the head-mounted display Microsoft HoloLens, following which an updated version of HoloLens 2 was released in February 2019. Microsoft's HoloLens uses MR technology to combine computer images with real vision to achieve touch, grasp and movement of holograms in a real and natural way. This is one of the most successful and practical AR headsets to date.

In April 2017, the AR start-up company RealWear launched the RealWear HMT-1 industrial head-mounted computer with AR function. In June 2018, it launched the RealWear HMT-1 Z1 explosion-proof industrial head-mounted computer that can be used in the petrochemical industry environment. The RealWear headsets are widely used in the industry since their launch.

In June and August 2017, Apple and Google, respectively announced their AR development platforms ARKit and ARCore, enabling software developers to develop a large number of AR application tools on the widely used iOS and Android systems.

On January 13, 2021, IDC released the top 10 AR/VR market forecasts in 2021, among which it was predicted that the Chinese market will remain the largest in terms of spending, accounting for 56% of the world[16]. China's National Development and Reform Commission issued the *Guidance on Promoting the Common Construction and Sharing of Public Training Bases*, together with the Ministry of Education, the Ministry of Science and Technology, the Ministry of Industry and Information Technology and other ministries and commissions, which proposes to guide and support the construction of public training bases, encourage the training of new industries, new technologies and new industries in public training bases, and promote the application of VR, AR, AI and e-commerce.

In the face of the rapidly developing VR | AR | MR industries in China and the United States, the European Media in the Digital Age: Action Plan to Support Recovery and Transformation[17], released by the European Union in December 2020, mentioned the desire to establish a unified VR | AR industry alliance to promote cross-industry cooperation to ensure Europe's leading position in the field. It is estimated that by 2030, VR | AR is expected to bring about 1.3 trillion Euros of output value to the global economy.

3. Exploration and application of AR wearable devices in the petroleum industry

The low oil prices have lasted for nearly a year and the global COVID-19 pandemic have forced oil companies to face problems such as cost reduction, remote work, remote assistance, remote maintenance and maintenance, etc. And major oil companies have been forced to push the digital transformation that is still trying to the forefront in advance. AR technology has become more and more concerned and applied by oil companies. Oil companies have begun to realize the advantages of AR technology in remote inspection and maintenance, remote monitoring, remote employee training and remote assistance. At present, oil companies have begun to cooperate with technology giants such as Microsoft and Google to develop special AR technology and wearable devices. Some AR technology start-ups and game engine development companies are also gradually participating to meet the special needs of oil companies. The current application of AR technology in the field of oil and gas has been gradually promoted.

British oil giant BP has begun to try the development and application of visualization technology and AR technology very early, and vigorously developed digital twin technology to carry out digital transformation efforts. In 2017, BP used AR startup Fieldbit's Fieldbit Hero smart glasses with live video feeds to enable experts in the control room to see what the field technicians were seeing, ensuring accurate diagnosis of problems. Then, using AR technology, the Fieldbit Hero smart glasses allow experts to overlay easy-to-understand visual instructions and real-time data from the control system into the technician's field of view as they work on equipment repairs. Through the use of AR technology, BP has improved their operational safety and operational efficiency[18]. An example of the application of Fieldbit Hero smart glasses in BP is shown in **Figure 1**.

Figure 1. Application of Fieldbit Hero smart glasses in BP.

In 2018, Chevron collaborated with Microsoft to equip its field technicians with Microsoft Hololens headsets for routine maintenance and expert remote instruction. With the advantages of remote assistance from HoloLens headsets, Chevron's local experts can provide remote guidance to factories and projects around the world, and employees at different factories and projects can also collaborate and assist remotely, thereby reducing travel costs and associated risks as well as to reduce and improve efficiency[19]. The application of Microsoft's Hololens headset in Chevron is shown in **Figure 2**.

Figure 2. Application of Microsoft HoloLens in Chevron.

In May 2018, Honeywell announced Skills Insight, a smart wearable device that combines the RealWear HMT-1Z1 headset and Honeywell Movilizer platform to support hazardous location field service operations. It can respond to voice and has functions such as operation procedure visualization, real-time data visualization, video capture and playback, voice control and search, remote expert standby, geolocation and navigation, asset visualization, emergency evacuation and rescue[20].

In 2019, in order to carry out digital transformation, Shell partnered with Honeywell and deployed the use of RealWear HMT-1Z1 head-mounted display in 12 countries and regions including the United States, China, and Germany, and had successfully resolved faults that occurred at sites through expert remote guidance. In July 2020, French oil giant Total deployed the RealWear HMT-1Z1 headset at its polypropylene plant in La Porte, Texas, USA. Through the headset's remote assistance function, Total was able to achieve significant results in terms of lowering expenses for experts travel costs and in the prevention and control of the COVID-19 pandemic. The application of the RealWear HMT-1Z1 headset in Honeywell is shown in **Figure 3**.

Figure 3. Application of RealWear HMT-1Z1 in Honeywell.

Middle Eastern oil giant Saudi Aramco's Osmania gas plant uses drones and headsets to inspect pipelines and machinery, helping the plant cut inspection times by 90%. In 2020, Saudi Aramco evaluated South Korean steel pipe manufacturers using AR equipment to remotely monitor equipment and material manufacturing. Saudi Aramco believes the use of AR headsets not only reduces the risk of the spread of the COVID-19 pandemic, but also complements Saudi Aramco's digital transformation plan.

Scholars such as De Souza Cardoso LF[21] investigated the application of AR technology in various industries from 2012 to 2018, involving construction engineering and facility management (AEC | FM), aviation, automotive, electronics | automation, energy, government, logistics and marine. It is found that AR technology has significant effects in improving production flexibility, reducing operation time, improving production quality, increasing operator safety and health, and promoting decision-making. In October 2021, Global Data, a well-known data analysis company, released a report on the Augmented Reality in Oil and Gas[22]. It is expected that within the next three to five years, AR technology have the potential to have a disruptive impact on traditional operating sectors of the oil and gas industry.

4. Application of AR technologies in oil and gas surface engineering design

4.1. Station design

The application of AR technology in landscape design, urban planning and engineering evaluation has been studied and explored by many scholars. Wang et al.[23] reported that the use of Visual C | C++6.0 development tools to implement AR landscape planning system which integrates the design objects with the real world provides good assistance to designers. Guan et al.[24] designed and implemented a virtual community planning system based on augmented reality, proving the advantages of augmented reality technology in community planning applications. Shen et al.[25] used AR technology to discuss the visual evaluation of large-scale construction projects. The results showed that the use of AR technology improves work efficiency and brings huge economic benefits. Phan et al.[26] created the ARC desk program based on AR technology and Google Earth, which is convenient for architectural design and urban planning.

AR technology, which has been explored and used in landscape design and urban planning, also has bright application prospects in the planning and design of oil and gas pipeline stations. At Chevron's Marlow oil field in the Gulf of Mexico, design engineers holographically projected 3D design models into conference rooms, allowing field engineers and experts to see exactly what the models would look like, test spacing, assess safety and verify other design issues.

The 3D models completed by CAD, PDS, SP3D, PDMS and other design software widely used in the design of oil and gas pipelines are often only stayed in the designer's computer. In the conventional engineering construction site, the final result is often the printed 2D plane drawings, which greatly reduces the effect of the 3D models. The use of AR technology can project holographic images of 3D models into the real world, visualize design results, and improve engineers' ability to evaluate and improve models.

For example, designers can edit applications in combination with the AR development platform, by importing design models and results into AR devices

such as head-mounted displays, and use AR to complete the projection of the 3D model of the station at the same scale on site. A review can then be made according to the physical state, personally experience the model placed on site to determine the rationality of the design, find problems before construction and deal with them in time. During the on-site construction process and after the construction is completed, the supervising engineer can abandon the time-consuming conventional 2D drawing on-site verification mode, and use AR technology to project the model onto the entity for comparison, so as to evaluate the matching degree of the physical object with the 3D design model and improve the accuracy and efficiency of quality inspection. Operation engineers can walk into the virtual process plant area projected on site, experience the ergonomics of equipment and piping, and familiarize themselves with the various functions of the plant area and simulate operations before the project is completed, which not only provides timely feedback to design improvements before construction, but also helps improve operational proficiency and commissioning safety.

The visualization function of AR technology enables all kinds of engineers to achieve an immersive state before the project is completed, and can play an auxiliary role in the entire project life cycle such as design, model review, construction and operation.

4.2. Line design

AR technology has been tried and applied in geographic information system and urban underground pipe network planning. Sun et al.[27] put forward the concept of ARGIS, which combines geographic information system (GIS) with AR technology to effectively combine the virtual digital space of GIS with the real-time interaction of AR. Chang et al.[28] proposed an outdoor hybrid based on RTK GPS combined with goniometric sensor AR system to discuss and verified its application in the underground pipe network 3D visualization. The use of AR technology can observe the direction and mutual position of various types of pipelines criss-crossed underground, and can carry out related query and analysis to effectively solve many problems in pipe network management. Zhou et al.[29] designed an AR system for urban underground pipe network using AR Core to realize the integration of virtual and real pipeline models, which can be viewed in real time in multiple directions.

At present, the design of pipeline routes is basically based on 2D plane section design. In the future, in the design of oil and gas pipeline routes, the 3D virtual-real combined display mode of AR technology will have certain development space in the following two aspects:

(1) In the design of large and medium-sized crossings of oil and gas pipelines, with the help of AR technology, the design drawings can be combined with GIS or Google Earth, where the design results can be combined with the digital 3D terrain of the site. This would enable the professional internal review and design scheme review stage to be carried out to allow participants to experience the actual effect of the design results, so as to give better guidance and help to improve the design results.

(2) After the design of the pipeline is completed, the AR application program, and measurement information such as the built pipeline, the built optical cable, the built road, and the house into 3D can then be imported into the AR program. The spatial position relationship of the existing facilities is helpful for judging whether the crossing method, crossing burial depth, pipeline direction, safety distance, etc. are reasonable.

4.3. AR supporting construction

He et al.[30] used the literature analysis method to analyze the literature on the application of AR technology in engineering construction from 2013 to 2019, and found that AR technology has been widely used in progress monitoring, quality control, assembly simulation and other aspects. It is pointed out that the problems of position perception, alignment and occlusion faced by AR technology during

construction need to be further solved. In June 2019, Petro China adopted the RealWear HMT-1Z1 in the fourth line of Shaanxi-Beijing to support construction, thereby reducing the travel cost of experts and designers.

The advantages of AR technology in coordinating construction are shown in the following two aspects:

(1) Remote guidance, cost saving. At present, the main way for the design unit to support on-site construction is to travel to the site through various means of transportation. Before the project is put into production, dozens of people from different professions are often required to provide support to the construction site. After adopting the AR technology, only a small number of major professional designers need to be deployed on the site in different areas and communicate with the leaders of each profession present in the unit office through the connection made with the AR equipment worn by the on-site designers, where the imported design results can be viewed by both parties. The professional person in charge at the unit office can then enter and mark the solution or voice communication guidance on the device and the on-site personnel can read it at any time to solve the problem. The adoption of AR technology not only reduces the cost of personnel travel, but also reduces the risks during the travel process. At the same time, because the round-trip time is eliminated, the efficiency of problem solving is improved. Additionally, the design director can also provide remote guidance for different projects in a short time, making it more convenient.

(2) Design results can be visualized in the field, digitizing workflows, increasing productivity and reducing errors. For example, the design parameters such as pressure, pipe diameter, wall thickness, burial depth, and crossing of the entire pipeline line are inputted into the AR system. With the positioning of the AR system and the on-site 3D holographic projection technology, the designer wears the AR equipment and sees it on site in real time. The virtual pipeline under construction or about to be constructed can call out the buried depth, crossing situation, pressure, pipe diameter and other information of the pipeline at any time, which improves the ability to find and solve problems, and improves the work efficiency.

4.4. Delivery of digital results

With the advent and rapid development of the 4IR era, in recent years, the field of engineering construction has gradually shifted from the traditional design and construction mode to the digital era[31-35]. For engineering design companies, the digital handover of design results is one of their development goals and a sign of digital transformation. The digital transfer of design results not only promotes the transformation and advancement of the engineering design company's business, but also has the most important effect of enabling the owner-operator to digitize the whole life cycle of the plant/station and its pipelines outside the station based on the digitally transferred data files and 3D models, which facilitates the asset management and operation and maintenance management. The AR/MR technology, with its functions of combining reality and reality, real-time interaction and data retrieval, can be combined with the 3D digital transfer results to play a role in staff training, pre-maintenance drills and guidance during operation and maintenance of production companies.

5. Conclusions and reflections

Low oil prices, COVID-19 and the Fourth Industrial Revolution have brought about the urgent need for digital transformation of the oil industry. New technologies in digital fields such as the Big Data analytics, Industrial Internet of Things, robotics and drones, Artificial Intelligence, Cloud Computing, 3D printing, Virtual Reality | Augmented Reality are gradually being applied, and Chinese oil companies have begun to explore and make efforts in digital transformation such as the creation of smart pipeline networks. Amid the global Covid-19 pandemic and the Industry Crisis brought about by low oil prices, increased efficiency and normalization of telecom-

muting (remote assistance, remote training, etc.) will facilitate the use and development of new technologies such as AR | MR.

At present, AR technology has gradually become popular with the wide application of smart phones and tablet computers. With the advancement of software and hardware as well as the combination of technologies such as the Internet of Things, Big Data and Artificial Intelligence, AR wearable devices will easily play a role in the oil and gas industry. AR | MR headsets with hands-free user interfaces, remote guidance, travel reduction, intelligent retrieval, data visualization, digital workflows, etc., have a positive impact on the design, construction, and operation of oil and gas pipelines, improving productivity, enhancing workplace safety, and reducing costs.

Conflict of interest

The authors declare no conflict of interest.

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