Analysis of Sensors in VR Equipment to 3D printer in IoT System

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Abstract. Virtual reality (VR) technology, artificial intelligence (AI), sensors and three-dimensional (3D) printing technology are all advanced and promising technologies. And these technologies are changing people's life and social development. Besides, Internet of Things (IoT) is a product of the development of modern communications, which is gradually applied to real life. However, there is no current system including VR, AI, sensors, and 3D printing at the same time. Therefore, this article presents an IoT system to integrate VR, AI, sensor, and 3D printer. By using VR equipment to implement human-computer interaction, using AI technology to assist users with operation and optimize 3D printing, using sensors to add functions and using 3D printer to obtain real-time manufacturing, this IoT system can simplify and optimize users' manipulation and it improves 3D printing technology. Because of the support of existing technology, this article explores the feasibility of IoT system and finds that it is a realistic system. This IoT system has positive effects on many industries like education, architectural design, and advanced manufacturing.

Keywords: Virtual reality, Artificial intelligence, Sensors, Internet of Things.

1. Introduction

Virtual reality (VR), artificial intelligence (AI), sensor and 3D printing are all advanced and promising technology. With the development of information technology, Internet of Things (IoT) is a trend that brings conveniences to people. There is an improving software that combines computer-aided design (CAD) with extended reality and 3D printing optimizing modeling and manufacturing processes [1]. However, this software is not so smart that untrained people are difficult to use it at the outset. Therefore, this article presents a small IoT system to simplify and optimize design and fabrication processes.

VR equipment to 3D printer (V2P) IoT system is an expandable network that integrate VR equipment, AI algorithms, sensors, and 3D printer. And this article explores how sensors used in V2P IoT system make the system versatile and accurate. To explain how sensors apply to V2P system, this article lists six functions of V2P system and different key sensors in the functions. Moreover, this article presents the restriction of current technology and prospect of V2P system. The purpose of V2P system is allowing more people participate in design and production processes, so users can get targeted and customized products from V2P system. Besides, because of the immersive and intuitive experiences provided by VR equipment, the V2P system can apply to numerous other areas except the fields in this text, such as military and sports.

2. Concept and Structure of V2P IoT System

2.1. Concept of System

As shown in Figure 1, V2P small IoT system includes both present technology and futuristic technology. For example, VR equipment such as apple vision pro, AI algorithms like AI image recognition algorithms, sensors like tracking sensors and 3D printers which may be suitable for a wide range of materials.

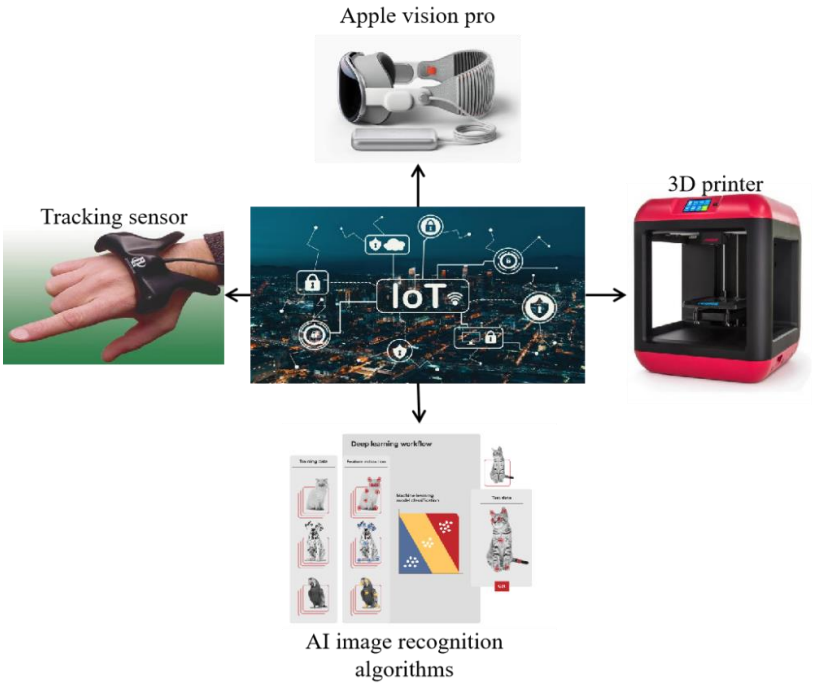

Figure 1. V2P system

Virtual Reality (VR) is a kind of advanced technologies that changes how human experience and interact with the digital world. VR gives users an immersive experience of virtual world that is a 3-D simulation of the real world by using tracking sensors and AI algorithms [2]. Nowadays VR is applied to many different areas, such as games, sport, education, aerospace and so on. A well-known example of VR equipment is apple vision pro which is a spatial computing equipment, and compared with usual VR equipment, vision pro has advantages on expanding surroundings, connecting to people around users and protect users' privacy. Moreover, vision pro is a new platform including Xcode, SwiftUI, RealityKit, and ARKit for developers to exploit and use [3].

3D printing is an emerging technology that has influenced industrial manufacturing. And 3D printing is more convenient to create complicated and customized shapes than traditional cutting methods. Furthermore, because of its low cost and high efficiency, 3D printing is used extensively in mechanical and plane engineering, automotive area, medical and dental area, aerospace, and defense. At present, there are three main types of 3D printing technologies which are vat photopolymerization, material extrusion and powder bed fusion. Vat photopolymerization is based on the idea of photopolymerization, which can fabricate high sophisticated structures due to its high accuracy and less supporting structure [4]. Material extrusion can use different functional inks to print rapidly, and the special inks includes conductive pastes, elastomers, and hydrogels [5]. Powder bed fusion is a manufacturing way where multi-material components can be combined into many products in high-complexity shapes and special design [6].

Internet of Things (IoT) is a kind of environments that have high diversity, heterogeneity, and intelligence via the participation of numerous sensors and big data algorithm. And with the development of information engineering, sensors, and computer algorithms, extending the Internet of Things to the "Internet of everything" is an inevitable trend arising from people's demand. Therefore, V2P IoT system is not only a closed system that operates independently without interaction with outside information, but also an extensible system which can connect to an external system to merge into a large network.

2.2. Structure of System

As shown in Figure 2, V2P system contains four parts which are not alone in single function. First, as the front-end equipment of the system, VR equipment can receive and process various incoming signals such as sound and visual signals. And VR equipment in V2P fulfills several functions: deep

human-machine interaction, virtual meeting, online shopping, scanner, design platform, remote control, spatial measurements and AI guidance and assistance. So, users can give orders (such as design) to the VR equipment, and then it provides feedback with an optimal series of actions in time. In this process, AI algorithms are used to optimize users' experience and meet the needs mentioned above. For example, deep learning can balance two different requirements which are user requirements and product performance. Meanwhile, many functions of V2P system are made possible by sensors in VR equipment, such as laser sensor using to scan. Next, VR equipment sends files containing parameters and materials of product to 3D printer.

3D printer, as the terminal of V2P system, has the functions of receiving information from VR equipment and printing out product rapidly. In the same way, adding various sensors and AI algorithms into 3D printer can optimize manufacturing process. For instance, using temperature and humidity sensors can create the right conditions for product. And material optimization algorithms in 3D printing can optimize the use of materials, reduce cost and waste, and improve productivity.

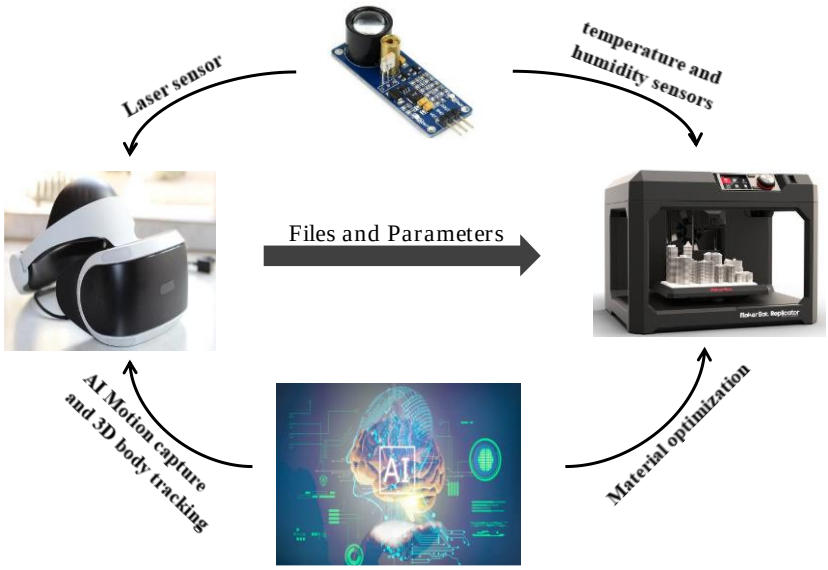

Figure 2. V2P structure

3. Functions and Sensors in V2P IoT System

3.1. Produce a New Thing

The first function is producing a new thing that users imagine and design. For example, if the user wants to build a smart house, he can use VR equipment to design for a 360-degree view of his house and details that can zoom in and out. Besides, he can design and decorate the house based on his own preference, and it is easy for him to design because VR equipment provides spatial data, alternative furniture and required materials. And with the help of AI algorithms, VR equipment can count the cost and provide optimization solutions. After the blueprints is finished, VR equipment sends it to the 3D printer. Finally, 3D printer produces the smart house efficiently and economically. In this whole process, there are some key sensors participating in it.

Firstly, Liping Yu's research team of KAUST have designed and created a kind of smart phone camera and built-in gyroscope-based application to get accurate displacement measurements. And this method is a low-cost and portable optical measurement which is based on smartphone. Moreover, the data from this smartphone gyroscope can measure how the camera coordinate system and the defined world coordinate system are rotated [7]. And because there are camera and gyroscope in VR equipment, which is similar to smart phone, this optical method can be used in VR equipment to obtain accurate measurement of off-axis structural displacements and calculate users' continuous displacements.

Secondly, in the research of Momtanu Chakraborty's team, they found 3D light detection and ranging (LIDAR) can be used to make maps of tree fruit crops. And they developed point cloud data processing methods which make mobile 3D LIDAR determine the realistic representation of canopy [8]. Furthermore, VR equipment can be used as a carrier of mobile 3D LIDAR mapping system with the use of LIDAR sensors. And the applications of this optical method in VR equipment can extend to creating a 3D map of a space or providing accurate data of measuring distances and detecting surface features, which provides experiential immersive spaces to users.

3.2. Scan and Restore

To accomplish this function, VR equipment is used to scan the destructed antiquities and analyze the material so that 3D printer can restore the antiquities with the help of the data from VR equipment. Furthermore, this real-time 3D reconstruction technology can be used to restore the high-quality cultural relics in the exhibition hall, and reproduces the historical relics in the form of VR so that the technology can give visitors immersive experiences [9]. And there are many sensors in VR equipment and 3D printer for completing this process.

Firstly, Teng Foong Lam's research team have developed a structured light sensor (SL) which has the ability to generate detailed 3D scans with submillimeter accuracy in real time. And in the research, they integrated SL sensors with robot's software, so it can adjust the projection pattern and the number of projections each scan in an adaptive way [10]. Therefore, in the V2P system, SL sensors can be combined with the software of VR equipment replacing robot mentioned above. And SL sensors can be used to scan three-dimensional antiquities accurately with high precision and produce real-time 3D images.

Secondly, in the study of Haoyan Yu's team, they provided a kind of microwave sensors that can identify internal flaws and characterize defect dimensions. And compared with other microwave sensors, this microwave sensor that uses resonance frequencies to find flaws adopts a low-cost vector network analyzer (VNA), so it is convenient and economic to use [11]. And because of its great performance on detecting internal tiny defects, the microwave sensor can be fitted in VR equipment to determine the tiny flaws in the antiquities. Therefore, the microwave sensor can help restorers identify the defects of antiquities better and more accuratly, and the defects are marked on three-dimensional tactile images in VR equipment. So restores can get clearer and more intuitive views of the defects and establish corresponding solutions to repair the antiquities.

3.3. A New Way for Shopping

Imagine that people can browse and buy things on VR equipment, and one of the advantages of shopping on VR equipment is that customers can check on the commodities in a 360-degree view and even can take apart the virtual objects to get more details. Moreover, the wearable devices can provide different senses of various objects to the users. And if the customers choose the virtual goods, then VR equipment sends the information, including parameters and materials, to 3D printer. Finally, the 3D printer can produce the goods in a few minutes. Therefore, this technology saves the need of transportation and simulates offline shopping. And here are the sensors applied in this process.

Firstly, Komi Chamnongthai's research team has developed a kind of haptic sensors that can propagate noise to the fingertips to enhance the haptic experience at numerous fingertips. So, the users' fingers can touch a virtual object and remotely sense its stiffness by using a single vibrator's stochastic resonance (SR) [12]. Thereby, with the usage of haptic sensor, users can touch the shape and hardness of virtual objects, which helps them make better shopping choices in virtual shopping mall.

Secondly, Yao Fan's research team has created a kind of sensor array to monitor the processes of products. With the usage of these quality control sensors, only useful variable information can be included in the analysis through targeted filtering methods of data generated by products, and the sensors also deal with the problem that the effective utilization of massive amounts of data generated during the process of quality control [13]. Therefore, quality control sensors in V2P system can

monitor the production process of 3D printer, and the products that customers choose in virtual shopping mall meet the required specifications and are of high quality.

3.4. Digital Twin, Surgical Simulation, and Customized Organs

A digital twin is a virtual replica of a physical product, process, or system that can be used to simulate, monitor, analyze and optimize its performance in real-time [14]. Thereby, VR equipment is a good digital twin carrier which connects real world to virtual world. So surgical simulation with AI assistance makes possible, which highly increases surgical success rate. Besides, physicians can collect data from the patient and create brand-new and customized organs in the virtual world. And in the V2P system, physicians can get the organs produced by 3D printers. There is no doubt that some sensors need to be used in this process.

Firstly, Zengchen Liu's research group created a kind of special pH sensor which is composed of a novel molecule. This fluorescence probe sensor has advantages on high sensitivity and fast response [15]. In the V2P system, pH sensors are used to monitor the pH of printing environment and organisms, which is crucial for live human cells.

Secondly, in the research of Frank Bunge's research team, they provided an oxygen sensor that monitors mammalian cells' oxygen uptake, and this sensor has reliable sensing, a small size and high integration and automation [16]. Therefore, when it is used in V2P system, its function is similar to pH sensors, but they can monitor the oxygen absorbed by the cells, which can be recommended as an indicator of the metabolism. And in the production process of 3D printing organs, adequate oxygen levels are necessary for the survival and function of the printed cells.

3.5. Material and Structure Test

Users can do material and structure test on VR equipment, which reduces test cost and adjusts products based on data. For example, when users design aircraft engines on VR equipment, they can simulate tests on the engines in the virtual world at the same time. And the optimization of material and structure provided by AI algorithms can reduce cost and improve engines' performance. And 3D printer can produce the engines in a short time. Therefore, there are some sensors used in testing aircraft engines.

Firstly, C. Song's research group presented distributed sensor arrays used in large and uneven surfaces such as unmanned aerial vehicle (UAV). Besides, after they developed a reduced-drift sensor measuring technique to optimize the output of sensor arrays, the flow sensor arrays are low-cost and mass-producible with good performance [17]. Therefore, as the flow sensor arrays used in UAV, the sensors applied to aircraft wings and engines can be used for wind tunnel tests which are airflow tests of airplanes.

Secondly, from research of Jim Mulrooney's group, they produced a kind of emission sensors which is an optical fibre sensor. This emission sensors can examine the optical spectrum of various gasses to analyze which gas it is and how much of it is present. And this type of emission sensor can identify various gasses more accurately and it is difficult to be corroded by chemicals [18]. In the aircraft engines test, the sensors are used to measure the emissions generated by the engine, such as carbon dioxide, nitrogen oxides, and particulate matter, which makes the aircraft produced by V2P meet emissions standards for aerospace.

3.6. Train AI, AI Guidance and Robots

Developers can train AI in VR equipment so that users can get AI guidance, which can replace customer service of real people. Furthermore, customers can get customized design from AI guidance, such as clothes and robots. Take robots for example, users can ask for needs of the robots, such as rescue robots or robot waiter, and AI can provide alternative options. And then, 3D printer produces the chosen robots and users can use VR equipment to control the robots. So, the sensors are centered on the printed robots.

Firstly, according to study of Liangsong Huang's research team, flexible proximity sensors are used for position detection, obstacle avoidance and allows robots to sense the proximity of the target objects. And compared with traditional proximity sensors, flexible proximity sensors have advantages on lower volume and larger detection range [19]. Therefore, flexible proximity sensors used in robots can enhance robot collision avoidance ability.

Secondly, from research of Yang Liu's group, rather than using the human eyes, robots with vision sensors can make measurements and conclusions on their own. And vision sensors have amounts of excellent features such as high accuracy and non-contact nature [20]. To be more specific, robots can capture visual information from their surrounding environment, and can accomplish tasks such as object recognition, tracking, and navigation.

4. Current Limits and Potential Application

4.1. Current Limits

There are many limits slowing the development of such V2P IoT system. Even though the most advanced VR equipment, apple vision pro, falls short of what V2P system needs. Moreover, there are three main 3D printing technologies which are suitable for different materials and use various 3D printers, so the restriction of 3D printing materials maybe the reason that 3D printing cannot be used on a large scale. And which 3D printer needed in V2P system is a kind of 3D printer that is suitable for a wide range of materials from hydrogel to metal.

Furthermore, with wide usage of VR equipment, more ethic problems are worthy of attention, such as users' private information. And the replication ability of 3D printer maybe infringe patents. To solve this problem, dynamic password of commodities or decentralized platforms and marketplaces can be used in VR shopping.

4.2. Potential Application

These V2P IoT system can be applied to many different areas. First, V2P in education. Using VR equipment can transform learning methods with immersive digital experiences, interactive environment, virtual experiments, simulation, vivid teaching tool and students' engagement and curiosity [2]. Besides, students can use VR equipment to design and use 3D printer to produce the model that the teacher needs in class, which can improve students' manual abilities and encourage their creativity. Second, V2P used by designers. VR equipment simplifies the design process and it is more intuitive than computers. Moreover, it is easy for users to work with each other with V2P system, because real-time data is transmitted between sections and V2P reduces the time for designing and producing while improves interaction between sections. Third, V2P in industrial production. The optimization algorithms in V2P reduces the cost of products and improves efficiency of mass production.

5. Conclusion

Based on research of V2P system and relevant literature, this article comes to the following conclusions. Firstly, V2P system structure and content have theoretical feasibility and plausibility. Secondly, V2P is a fundamentally malleable and shapable system that it can connect other devices via other IoT systems as people need. Thirdly, as a wearable and augmented reality device, VR equipment has advantages on portability and sense of immersion, so it can substitute for computer in daily life and work. Fourthly, adding AI algorithms in V2P system can make it more sophisticated intelligence and it is convenient for users to operate the system with AI assistance. Fifthly, sensors can provide high-precision information collection and processing, low cost, and versatility to V2P system. Sixth, 3D printer can produce quickly and efficiently, and manufacture products of complex shapes and structures. Last but not least, V2P system has promising market and application prospects

in many different areas, which will influence people's lifestyles and work. Furthermore, V2P system can lead to the development of relevant industries.

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