Review of the Research on Augmented Reality Maintenance Assistant System of Mechanical System

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Abstract: In order to ensure the normal operation of mechanical system and solve the problems of complex structure and insufficient cognition caused by mechanical system updating, the advantages of applying augmented reality technology in the field of fault diagnosis and maintenance are analyzed. Firstly, this paper summarizes the application of augmented reality technology for maintenance assistance cases at home and abroad, analyzes its industry characteristics and application advantages, then summarizes the key technologies of augmented reality, and finally prospects the development trend of the system application.

1. Introduction

With the progress of science and technology and industrial development, all kinds of mechanical equipment are in the process of innovation. The structure of new equipment is complex, the use experience is insufficient, the corresponding learning cases are lack, and the maintenance personnel are lack of cognition, which leads to low maintenance efficiency. In order to ensure the maintenance efficiency, maintenance personnel need an intuitive and efficient auxiliary tool.

In recent years, with the development of computer vision and image processing technology, Augmented Reality (AR) technology appears in the public's field of vision. AR mainly refers to adding virtual scene or related information in real environment to enhance users' perception of real scene, which brings new ideas for mechanical maintenance[1]. At present, many units at home and abroad have studied the maintenance mode based on AR and its key technologies, and achieved certain results. AR can be used to assist maintenance personnel to improve efficiency. In order to solve the problem of insufficient maintenance cases of new equipment, the intelligent diagnosis and reasoning technology can be used to analyze the failure mode and consequence in the design process, and establish a database to help the maintenance personnel quickly and accurately find the fault cause. This paper mainly expounds the key technology of AR maintenance auxiliary system of mechanical system, analyzes the application advantages of the system, points out the existing problems and summarizes the development trend, hoping to provide new ideas for the research of mechanical maintenance.
2. Development of AR maintenance assistance system

AR maintenance assistant system refers to using AR technology to visually process the data available in the maintenance process and the operation steps required to complete the maintenance, so as to strengthen the user's perception of the real world, so as to realize the purpose of assisting maintenance personnel in fault diagnosis and maintenance[2]. The key part of the system is fault diagnosis and on-site off-line maintenance assistance. It has the functions of maintenance training and remote maintenance guidance.

2.1 Research progress abroad

Many foreign countries, especially European and American countries, have recognized the advantages of AR in maintenance and other industries for a long time. Therefore, the research on AR started earlier, many technologies are more mature, and a series of achievements have been made, which represents the advanced level of the world in this field.

Figure 1 AR maintenance guide glasses launched by German BMW company

In the early 1990s, Boeing company of the United States used AR technology to generate virtual wiring diagram, which provided guidance information for technicians in aircraft assembly and maintenance work, so as to assist engineers in assembling complex power cables and connectors on aircraft[3]. In 1993, Professor Steve Feiner's team developed a knowledge-based AR for maintenance assistance system, which uses AR to simulate and display the position and disassembly mode of the tray in the laser printer, so as to guide the user's specific maintenance operation[4]. In 2007, the United States Air Force joint air force research laboratory, combatant preparation research department and Columbia University launched the AR maintenance and repair research program. The program mainly explores and studies the feasibility of the application of AR in the maintenance and support of weapons and equipment, aiming to improve the effect of equipment maintenance and maintenance training. The prototype system is verified in the maintenance activities of military armored vehicles[5]. In order to encourage the application and promotion of AR, the German education department funded the Arvika project[6]. BMW company introduces a special type of intelligent glasses, which uses AR to guide maintenance workers to carry out vehicle maintenance. The intelligent glasses can display the corresponding repair operation steps and suggestions according to the vehicle fault diagnosis information[7].

2.2 Research progress in China

The research on AR technology in China started relatively late. At the beginning of this century, it began to explore the theory and application of AR technology.

The researchers of Guangdong University of technology use color to judge and detect. In the AR environment, the printer is taken as an example to design the maintenance system. Beijing University of Posts and Telecommunications studies the application of AR in mechanical equipment maintenance from the method of edge tracking. Nanjing University of Aeronautics and Astronautics has carried out a series of in-depth research on AR based civil aircraft maintenance, including the composition, construction and interaction mode of maintenance guidance system. University of Electronic Science and technology of China also has related research in the field of equipment maintenance. Its auxiliary maintenance system includes image recognition and tracking positioning, virtual information database, image fusion and display and other important parts. The 0glass AR intelligent glasses full terminal
work assistance and training system designed by Shenzhen Augmented Reality Technology Co., Ltd. shows the advantages of intelligent maintenance in the aspects of work, management, training and knowledge accumulation.

![Figure 2: Work aid and training system based on AR intelligent glasses in Shenzhen Augmented Reality Co., Ltd.](image)

### 3. Key technologies of system implementation

#### 3.1 Technical framework of AR maintenance assistance system

The key technologies of mechanical system maintenance assistant system based on AR mainly include AR (virtual model tracking registration technology, intelligent human-computer interaction technology) and intelligent fault diagnosis technology.

AR is mainly used to overlay all kinds of auxiliary maintenance information into the real world to enhance the perception of operators. Among them, the tracking registration technology scans the environment, calculates the user's posture, accurately locates the virtual information, and ensures the accuracy of virtual and real fusion. Intelligent human-computer interaction technology allows users to operate the system through gestures or voice according to the existing virtual information and the system will give feedback.

Intelligent fault diagnosis technology is mainly used to assist users in fault diagnosis and improve efficiency. First, collect the fault information and the corresponding solutions, establish the fault information database. Secondly, diagnose the faults according to the fault information collected at the scene, and finally adjust the corresponding causes and solutions, and display them in the view of users through AR. This technology has the function of learning. Aiming at the uncertainty of fault, it records the unrecorded cases and improves the accuracy of fault diagnosis.
3.2 Tracking registration technology

AR overlays the virtual information and the real environment, so that users can obtain information more intuitively to achieve the effect of enhanced perception. In order to ensure the accuracy of information acquisition, virtual information must be accurately correlated with the real world, which is the main role of tracking registration technology. At present, this technology is mainly divided into three types: plane identification tracking, no identification tracking and three-dimensional identification tracking.

Plane label tracking takes an object as the tracking object, identifies the object in the environment, detects the edge, discretizes it into a series of feature points, collects the location information of the feature points, and then registers the virtual information. At present, this registration method is adopted by the Metaio AR SDK and Vuforia SDK. This method has high positioning accuracy, but it is very dependent on markers. Once the markers are not recognized, tracking registration cannot be realized. Unmarked tracking technology mainly uses the depth camera to carry out SLAM (simultaneous localization and mapping) of the environment. Firstly, it scans the environment and calculates its own position and posture. Then it constructs a simplified environment model and integrates with virtual information to realize tracking registration. The technology breaks away from the restrictions of markers and improves the robustness of the system, but the positioning accuracy is not high, which is suitable for static scene tracking registration. 3D label tracking takes a specific 3D object as the tracking object, scatterers its surface features, and realizes tracking registration according to the position information of each point. This method is mainly for the motion scene, allowing the system to complete registration from different angles.

Single tracking registration method has limitations. In the practical application process, a combination of multiple registration technologies can be used to ensure the accuracy and robustness. For all kinds of mechanical systems, it is necessary to carry out maintenance in static state. In this process, we can use plane identification tracking to help the system locate, and then use SLAM technology to track and register in real time to ensure the robustness of the system.

3.3 Intelligent Interaction Technology

In the AR maintenance assistant system, there are a variety of interaction modes. From the traditional keyboard and mouse to language gesture interaction, the operation mode of the system has achieved a qualitative leap in convenience and efficiency.

Mouse, keyboard and touch are the first common means of interaction. These hardware devices are
cheap and can’t provide a good interactive experience, and lack of immersion and realism. After that, a
portable projection interactive technology was developed, which projected the interactive picture into
a plane, and users could interact with the system in the projected plane, such as OmniTouch developed
by Microsoft[9]. In recent years, the intelligent interaction mode has gradually matured, which takes the
user's hand and voice as the interface, and captures the gesture and voice as the system input. This way
is intuitive, natural, and more in line with human operation habits. In the process of mechanical system
maintenance, the use of gesture and voice control can reduce the difficulty of system operation and
improve the work efficiency of personnel.

3.4 Intelligent fault diagnosis technology
Fault diagnosis technology refers to mastering the operation status of the equipment in operation or
without dismantling the equipment. According to the information obtained from the test of the
diagnosed object, we can judge whether the object is in abnormal or fault state, find out the fault
location, judge the cause of the fault and predict the development trend of the state deterioration[10]. At
present, the mechanical system is more precise, the structure is more complex, the failure rate is higher,
and the cases are less, so it needs a lot of manpower and material resources for detection, and it also
needs time for personnel training. The existing solution is to use the failure mode and effect analysis
(FMEA) technology to estimate the possible problems in the design process, and to build solutions for
these problems. When the actual equipment problems occur, it needs to refer to the manual for
maintenance, which is inefficient.

With the development of modern science and technology, mechanical system gradually tends to be
information-based and intelligent, which puts forward higher requirements for fault diagnosis
technology. At the same time, the development of computer technology makes the modern fault
diagnosis technology develop towards the intelligent direction. The intelligent fault diagnosis
technology such as Petri net, fuzzy set theory, fault diagnosis expert system and artificial neural
network have become the mainstream of current research.

The occurrence of fault has uncertainty. In view of this uncertainty problem, Bayesian network
fault diagnosis technology can be used to establish expert system to diagnose the fault efficiently and
accurately. Bayesian network is a probability network which combines graph theory and probability
theory. It is composed of directed acyclic graph, nodes and directed line segments connecting nodes.
Nodes represent random variables and have their own probability distribution. The directed line
segment represents the causal relationship between variables and is quantified by the corresponding
conditional probability. All nodes are connected by directed line segments to form a complete but not
closed-loop network topology. The parameters of nodes and directed line segments can be counted and
quantified in the process of design, production and processing of each component, which supports the
fault diagnosis of the whole network.

In the actual fault diagnosis process, because of the uncertainty, there will be cases that can not be
predicted. Bayesian network is needed to learn structure and parameters. Structure learning is to
determine the most appropriate network topology structure of Bayesian network model by using the
training sample data set and the probability obtained by expert evaluation as far as possible. It changes
the number of directed line segments in the existing topological structure or its direction to make the
relationship between nodes more reasonable. Parameter learning is to learn the local conditional
probability distribution of each variable in the network under the given network topology, which
optimizes the existing node parameters to make it more in line with the actual situation.

4. Existing problems and development trend
Although in recent years, AR in China and abroad has developed rapidly and achieved certain results,
but there are still some deficiencies in real-time, interactive and intelligent.

4.1 Real-time
Due to the complexity and uncertainty of the fault and the limitation of the background processing
ability of hardware devices, the current AR devices may cause the system to jam or crash due to the huge data. In order to solve this problem, we can simplify the data in the process of building the system, reduce the pressure of background computing. In addition, 5g technology can also be used for remote communication, so as to make remote contact when new cases appear, so as to ensure rapid troubleshooting.

4.2 Interactivity
Intelligent human-computer interaction has become the main development direction of the current interaction technology, but there are few interaction channels, low recognition and low user acceptance. The gesture control posture is single, which can not be operated completely according to personal habits, and the recognition accuracy is low. The ability of speech recognition is limited, only a single word can be recognized. In the future, gesture interaction, as a very intuitive way, will develop towards personalization and precision. Users can customize the gesture input of the system according to their own habits. At the same time, voice control can recognize more and longer sentences and even communicate with users.

4.3 Intellectualization
Single intelligent diagnosis technology has certain defects, for example, Bayesian network reasoning speed is fast, but due to the uncertainty of the fault, the accuracy of the diagnosis results has a certain deviation; neural network diagnosis speed is fast, high precision, need a large number of samples for preliminary training, which is difficult in engineering application. Therefore, the future intelligent diagnosis technology should pay attention to the combination of various ways, learn from each other, give full play to the advantages of intelligence, improve the speed and accuracy, reduce the cost of personnel training, and improve the maintenance efficiency.

5. Summary
With the development of modern computer technology, digitization and informatization are the inevitable trend of mechanical development, which brings new challenges to the maintenance of equipment. The maintenance assistant system based on augmented reality is an effective response measure, which can significantly improve the maintenance support efficiency of mechanical system while reducing the time cost of personnel training. At present, the research on Augmented Reality Technology in China is very limited. In the future, this kind of system will be widely used in the maintenance of various equipment.

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