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Augmented Reality Technology and Its Application in Aviation Industry

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Abstract

With the development of digital technology, the wide application of augmented reality technology in aviation manufacturing industry is also possible. Through the introduction of the development and key components of augmented reality technology, this paper summarizes the application of augmented reality technology in aircraft assembly, maintenance and inspection of Boeing, Airbus and other aircraft manufacturers, and analyzes the research on augmented reality technology in domestic aviation industry The current situation and development trend provide certain technical support for the specific application of augmented reality technology in the whole life cycle of civil aircraft.

Keywords: Augmented Reality;Aircraft assembly; Virtual assembly;Aviation Industry

1. Introduction

Aircraft, as a highly integrated system engineering, has the characteristics of large geometric size, complex structure, large number of parts and so on. From the preliminary design, manufacturing and assembling to its customers' support in the later stage. Obliviously,Traditional paper documents or electronic documents for its information transmission and communication, can not meet the requirements of research and design's requirements.During the processing of industry information, Augmented reality[1] (abbreviated as AR),as a revolutionary virtual reality fusion technology, is becoming more important. AR weakens the boundaries between human and machine, virtual world and physical world, and makes the real physical world and digital world seamlessly integrate [2], which greatly reducing the restrictions on staff's visual space ability, and strengthening their cooperation. AR improves the perception of important information, expands the channels and scope of information acquisition, and improves staff efficiency and shortens the cycle. Now it has become one of the key contents of major aircraft manufacturers.

2. Development of augmented reality technology

The concept of AR was originally proposed by Boeing engineers in 1992, Tom Caudell and David Mizell [3], as they designed the auxiliary wiring system, which could add the text information of wiring path and related text drawn by simple lines to the vision of the mechanical designers in real time, and gradually display the disassembly process for it, which greatly reduces the error probability in daily wiring. They also thought that AR had a low demand for computer processing capability compared with virtual reality. At the same time, it was required for AR to improve its positioning technology in order to make the virtual world and the real world better integrate.

In 1994, "reality virtual continuum" was proposed by Paul Milgram and Fumio Kishino [4] , which described the span from real environment to virtual environment. Real scene and virtual scene were distributed at both ends, and AR was close to the real environment, augmented virtuality was close to the virtual scene, and the part in the middle was called mixed reality, as shown in Fig.1, In 1997, another definition of augmented reality was proposed by Ronald Azuma[5] proposed , which believed that augmented reality technology should have three specific features: 3D registration, virtual reality fusion and real-time interaction. At present, the definition of augmented reality proposed by Milgram and Azuma has been widely accepted by researchers engaged in AR technology all over the world.

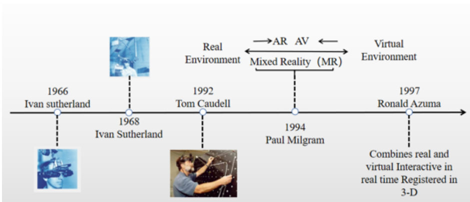

Figure 1. Development history of AR

With the development of the corresponding technology, the application field of AR technology is becoming more and more extensive. In 1992, the US Air Force developed the virtual fixtures [6], and Columbia University developed the KARMA repair help system. Then in 1999, the AR Tollkit project [7] was developed by Kato Hirokazu of the University of advanced science and technology in Nara, Japan. Its main function was computer tracking, first of all, it need to recognize 2D objects successfully, and then track the real objects, so that virtual objects could move synchronously with real objects. In 2000, Bruce Thomas of University of South Australia developed AR quake project [8], which brought AR to outdoors' real scenes. In 2007, the application of AR technology in the medical field began to be developed. In 2008, AR technology was directly settled on Wikitude's AR travel guide by the mobile phone, and mobile phone users can use their Android phones to view the relevant information of the places they are visiting in real time [9]. In 2012, Arvika project was proposed M Hamadou et al, which is to explore the application of AR technology in product design, production and service [10,11] in Germany. On March 17, 2020, the company of Edgbee and the company AFWERX announced that they had signed a contract to develop and integrate Argus AR software for the US air force, in order to improve the situation awareness ability of the US Air Force in complex operational scenarios [12].

In recent years, many large enterprises such as Microsoft, Google, Facebook and Sony have entered the AR industry one after another, which has greatly accelerated the development process of AR technology. At present, AR technology has been widely used in the fields of medical treatment, education, entertainment and cultural relic protection. The application of industrial AR technology is also changing with each passing day. As a world-famous aircraft manufacturer, Airbus and Boeing have successively used AR technology in the fields of aircraft assembly, maintenance and customer service.

3. Augmented reality system and key technologies

3.1. Constitution of augmented reality system

3.1.1Combination of Virtual and Reality

Compared with VR technology, one of the most important differences of AR technology is the way of combination with the real world. Unlike VR technology tends to create a pure virtual environment isolated from the real world, and AR adds virtual content on the real world. Based on optical wave guide, projection and micro lens array technology, the real world and virtual content can appear in the user's field of vision at the same time. By adjusting the spatial positioning and projection relationship, people can get the effect that the virtual content exists in the real world.

3.1.2 Spatial registration

The core of AR technology is its connection with the real world. In order to establish this connection, the real world should be perceived firstly, most of all, the spatial location information is the key important, that is, spatial registration. Through space registration, the 6-DOF information of AR device (eye position) relative to the real world can be obtained in real time. This information forms a bridge between the virtual world and the real world, which makes it possible to overlay virtual content in the real world.

3.1.3 Real time interaction

As a basic feature of VR technology, interactivity is an important feature of AR technology.AR is based on the real world, perceive and identify the information of the real world through installation sensor in the device, according to the actual application scene, and using the visualization processing, the information is displayed in the user's field of vision, so as to strengthen the user's perception of the environment, and help users obtain more abundant information.

3.2. Key technologies of AR system

Tracking registration has been attracted attention as a core problem of AR application, By realizing accurate camera tracking, the target attitude can be recognized according to its calculation, and the virtual 3D model can be accurately rendered into the real scene, so as to realize the virtual reality fusion of augmented reality. At present, in the aspect of augmented reality camera tracking registration, three ways are provided in tracking registration: model-based, tag based and unmarked camera tracking registration methods.

3.2.1 Model-based tracking registration

Camera tracking is carried out, according to the model information of existing objects in the real scene. By constructing the model information of the tracked target in advance, when the camera sees the tracking target again, it can compare the object information available at the current position with the known model, and then get the pose relationship of the camera relative to the world coordinate system at the current position, so as to realize the virtual reality fusion process of augmented reality. This way often needs to have strong prior information for the tracked target or scene,as shown in Figure 2.

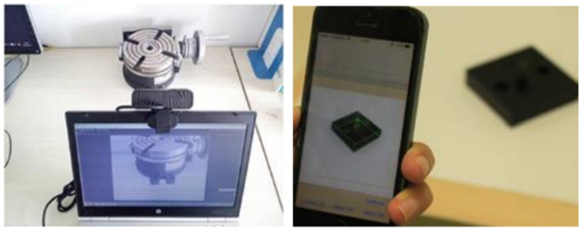

Figure 2. Model-based tracking registration[13]

3.2.2 Tag-based camera tracking registration

The pose of the camera can be calculated by recognizing the marked points,which should be prefabricated, It pastes the corresponding mark points in the scene to be enhanced, so as to facilitate the subsequent extraction and recognition of the image features of the mark points, and realize the tracking registration of the camera. At present, there are some mature development tools based on tag augmented reality, such as Alvar, ARTag, ARToolKit, etc. By pasting these identification points in the real scene, when the camera observes the identification point, a series of image segmentation and detection methods based on computer vision are used to calculate the pose transformation relationship between the camera and the marked point, so as to achieve the stable tracking registration.

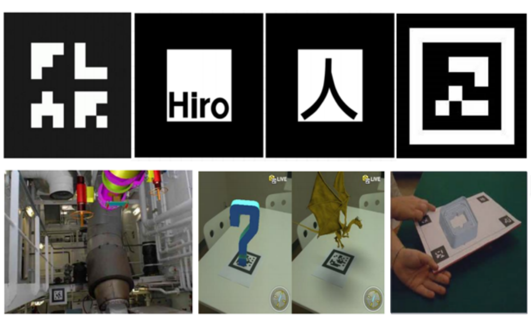

Figure 3. Augmented reality application scene based on marked points [13]

3.2.3 Unmark-based camera tracking registration

Without any prior information of the scene, the tracking registration of the camera is realized by autonomous positioning. This method overcomes the shortcomings of the model-based and tag- based tracking registration methods mentioned above to a large extent. It does not need any prior information in the scene, but only needs the existing image feature information such as points, lines and textures in the scene to realize the tracking registration of the moving camera, and then provides accurate attitude estimation for augmented reality.

With the improvement of computer vision algorithm and mobile computing ability, the tag free tracking registration method has made great progress. Among them, visual odometer, as an incremental transfer method of camera pose tracking, can obtain the natural scene information of the environment through the camera, which can realize the current pose estimation of the camera. However, because there are only incremental tracking threads and there is no corresponding closed-loop and global optimization strategy, the camera tracking error will accumulate with the increase of tracking distance. Therefore, based on the visual tracking of the front-end, the visual Slam (simultaneous localization and mapping) framework, which realizes the real-time optimization of the back-end, is a more mainstream camera tracking method in markerless mobile augmented reality.

4. Application of AR technology in foreign aviation industry

4.1. Boeing Company

4.1.1 Application of AR glasses

Boeing started using AR glasses in 1995, but it did not put forward strategic deployment because of the limitations of the battery, size and network to the back-up display and technical software at that time[14].

In order to obtain the enterprise application of Google glasses, Boeing and APX laboratory jointly developed a glasses application. Its working principle is that the engineers wearing glasses scan the two-dimensional code, pull the wireless bundle software, and then scan another code to load the assembly instructions. At the same time, they support the glass voice command, It allows users to transfer the information they see to other technicians. The program is used to sort out a large number of complex electronic circuits in the aircraft. Compared with the traditional method of comparing with the function manual, the error rate is reduced by 50%, and the time is shortened by 25% [15].

Figure 4. Boeing's electronic circuit arrangement based on AR glasses

4.1.2 Application of aircraft assembly

As an important part of the aircraft assembly, the cable installation work, its wiring harness is very complex, and there are many interference factors, so a lot of information need to be considered and processed during the installation. Using the traditional method, that is to say, by consulting and analyzing the drawings and thinking about the wiring installation method, the work will be very complex and the probability of error is also high. According to the report of Boeing company in January 2018, for the first aircraft wiring task, compared with the traditional working mode based on 2D information, the information acquisition amount of the new method based on AR is increased by 90%, and the time is saved by 30% [16].

Figure 5. Boeing's AR technology test in assembly plant

4.2. Airbus Company

4.2.1 Application of AR glasses

For AR glasses, Airbus has developed an overall solution for aircraft design and manufacturing based on Hololens, which includes scene solutions such as training, remote cooperation and maintenance. The test shows that the latest Hololens 2 can speed up the test process for Airbus designers and reduce the total design time by 80% [17].

In the frame of A350 instrument panel, all kinds of wiring harness and pipes are often in a mess, and the whole installation process is extremely complex. The engineers of Airbus used white light projection combined with Hololens overall solution to allow operators visually view and accurately operate and install, which can save 25% of the time [18],as shown by figure 6.

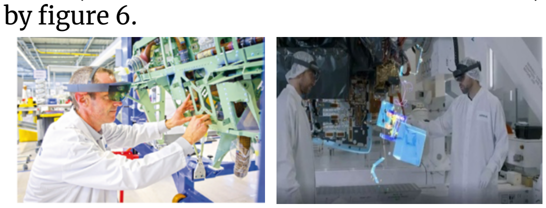

Figure 6. Some design scenarios of Airbus based on Hololens 2

4.2.2 Application of aircraft assembly

In recent years, Airbus attaches great importance to the application of portable VR / AR technology in the whole life cycle of aircraft, and actively explores the application of AR glasses and pad in aircraft assembly. In order to realize the quality standardization in the global production facility network, MIRA / SART augmented reality solution (MIRA / SART) was launched in 2001, which has been used in the production lines of A320, A380, A350 and A400M in Airbus France , Germany and Spain. It is reported that on the A380 fuselage, which can reduce the inspection time of 60000-80000 brackets from three weeks to only three days [19].

Figure 7. MIRA/SART for structural bracket detection

4.2.3 Application in aircraft maintenance

The maintenance cost of airlines is a main cost expense, so shortening the maintenance time of aircraft becomes one of the important ways to reduce the operating cost of airlines. In order to achieve these goals, AR systems [20], providing mobile and real-time functions for maintenance personnel to simplify and accelerate their maintenance activities. AR technology is used to guide operators to optimize the maintenance path automatically through various aircraft areas. Users can directly guide themselves to the next step of the maintenance process according to their own position.

It can be seen that Airbus has successfully applied AR technology to the design and development, manufacturing, assembly, maintenance and other aircraft life cycle processes of various aircraft types, which makes many problems in product design, fixture design and process planning be found in advance, reduces the trial production of physical samples, speeds up the mass production of aircraft, and saves a lot of time and cost in the process of research and design.

5. Application of AR technology in aviation industry of China

Aviation industry corporation of China(AVIC) has carried out relevant technical research in the field of aircraft maintenance and assembly. In order to apply AR technology to the assembly site, Xi-An Aircraft

Industry Company has carried out AR field application research on the wing rear beam assembly of "Xinzhou" 700 aircraft through "millions of innovation fund" [21]. The technicians of manufacturing Engineering Department considered the characteristics of aviation products, focusing on three-dimensional digital model lightweight technology, three-dimensional registration technology, AR equipment field application technology to carry out technical research one by one.

1) Three dimensional digital model lightweight technology: Using Hololens glasses to determine the corresponding digital model lightweight software, by using patch merging, deleting the invisible model, removing part of the model details to carry out digital model lightweight;
2) Three dimensional registration technology: For the feasibility analysis of current technology and the complexity of field assembly environment, the two-dimensional code marking method is used to mark the digital model and physical object;

3) AR equipment field application: From the point of convenience and safety used in industrial field, the application of unity animation editing software, considering of AR version AO segmentation and reasonable setting of calibration points. By analysis and solve the technical details to achieve the accuracy requirements.

At present, the project has completed the preliminary exploration and research on the assembly of "Xinzhou" 700 wing rear beam, and applied on its complex structure and many parts.

Beijing aircraft technology research institute of COMAC has set up a digital simulation and information technology laboratory. For the AR technology, focuses on the key technology research used in aircraft design and evaluation. In order to achieve high-precision position and attitude tracking, it carried out the preliminary discussion of optical-inertial hybrid tracking, The position information was obtained by optical equipment, and the attitude information was obtained by inertial equipment to achieve accurate and stable position and attitude tracking. Based on this scheme, the preliminary virtual real fusion was realized, as shown in Figure 8.

Figure 8. Virtual reality fusion based on optical - inertial hybrid tracking

Based on Hololens2, they also researched remote rendering and human-computer interaction technology. Used WiFi to establish TCP connection through IP address search for Hololens2 and PC. After establishing the connection, the program established a switching link (image data buffer) for graphic data transmission. At the beginning of rendering, the host program loaded the model to be rendered through the Assimp library, and Hololens2 sent the current location information and interaction information to the PC. the program processed the model information and Hololens2 input, and sent the frame data to Hololens2 for playback through the rendering process. The schematic diagram of the whole process was shown in Figure 9.

Figure 9. Schematic diagram of information transmission between PC and Hololens 2

6. Conclusion

This paper elaborated on the development, key components, technical characteristics and application advantages of AR technology, and focused on the application of AR technology in aircraft manufacturers at home and abroad. Combined with the author's understanding of AR technology, the following conclusions can be drawn:

1) The advanced nature of wearable devices and the durability of the wearable display devices are all slightly inadequate, such as the lack of battery life of AR glasses, the lack of perfect system platform such as graphics rendering /CAD model and user interface, etc.
2) The application of AR technology in aviation industry mainly focuses on maintenance, assembly, remote training and other fields. Due to the lack of reliable 3D tracking technology, large-scale operations such as the whole fuselage cannot be realized;
3) With the commercial promotion of 5G technology, the transmission rate, delay, connection density and mobile speed will be rapidly improved. The realization of complete cloud rendering equipment and the display equipment with head will be improved greatly,so AR technology will be widely used in the life cycle of civil aircraft development.

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