Lightweight Design of Aircraft Virtual Scene and Wireless Transmission

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Abstract. The concept of virtual reality, which is an important role in aircraft simulation training, was first proposed in the aerospace field in the 1960s. In recent years, with the development of hardware technology, virtual reality technology has been widely used in games, entertainment, medical and other civilian fields. In the field of civil aircraft, virtual reality technology mainly focuses on simulated flight, cockpit pilot training, aircraft maintenance training, etc. This article proposes a customer-oriented aircraft virtual scene design and implementation method, and describes the design process from aircraft 3D model construction, lightweight processing, virtual scene rendering, and WebRTC-based wireless video streaming. The main technical difficulties solved in this paper include two parts: one is to convert the existing aircraft 3D engineering model into a polygonal model that can be used for VR rendering, and the other is to realize the problem of multi-user online interactive access to virtual scenes. Through this system, users can do engineering evaluation and experience evaluation during the whole process of aircraft product design, development and sales. The application scenarios designed in this paper further expand the application of virtual reality technology in the field of civil aircraft development and lay the foundation for the development of more application scenarios in the future.

1. Introduction

Virtual reality (VR) technology is the use of computer simulation technology to create a three-dimensional virtual world with simulated vision and other senses, making users feel as if they are immersed in the real environment and able to observe the three-dimensional space in real time with no limits. VR technology has the following 4 characteristics [1]: perception, immersion, interactivity, autonomy. This technology came into existence in between the 1960s to the 1970s, and was first introduced in industrial manufacturing, which is the basic application of other types of ‘virtual reality’. VR technology began to form and develop in the 1990s [2], and has been widely used in games, e-sports, entertainment and other fields. With the rapid development of computer hardware technology and the substantial cost reduction, virtual reality technology has gradually become a research hotspot in various fields, e.g., medicine, architecture, industrial manufacturing, and military (especially in simulation training), industrial design, and also interactive experience. Modern aircrafts are highly integrated and the development cycle is getting shorter, VR technology has become an effective method to support the civil aircraft design and manufacture. In the process of aircraft design, with the application of VR technology, simulation demonstration of the aircraft performance, ergonomic analysis, overall layout, assembly and maintenance evaluation were carried out in advance, so that the closed-loop iteration of "design, analysis and improvement" was realized [3]. This paper introduced a potential scenario in civil aircraft design and manufacture process with VR technology. Such scenario aims at improving
customer-oriented experience and engineering evaluation, and is also able to extend the application of VR technology to the entire life cycle of product design in the field of civil aviation, including research and development, sales and after-sales process.

2. System Implementation

2.1. System Development Process

The system development process includes: product function definition, modelling design, UI interface design, network architecture design, product testing, etc.

In the product function definition stage, the user’s actual needs in the scenario are converted into product function definitions.

The model development stage is a specific implementation phase. It involves the entire process: from the original CATIA engineering digital model of the aircraft to the final complete virtual reality scene. It is also the core technology of the system, which directly affects the authenticity of the virtual reality scene.

In the UI interface design stage, a practical, beautiful, user-friendly, and implementable human-machine interface is mainly defined from the perspective of human-computer interaction.

The network architecture design is another key module in the article. At this stage, the scene rendering program is mainly transmitted to each user terminal through the wireless network, and the user terminal can control the background rendering program in real time. The design process is shown in Figure 1

2.2. Model Building

There are three main types of problems faced by virtual reality technology in practice [4]: Modelling method, display technology, human-computer interaction and equipment. The first problem to solve is the modelling technology, which generally involves a large amount of modelling work and high cost of model development. The design of traditional equipment manufacturing products generally uses CAD-based parametric modelling technology, and the software used is generally UG, PRO/E, CATIA, SolidWorks, of which UG is mainly used for model design, PRO/E is mainly used for electronics, and SolidWorks is mainly used for the design of mechanical products, while CATIA is often used in industries such as automobiles, aerospace, and ships. These software-designed models can all be called parametric models, which are accurate models constructed from points, lines, and surfaces with precise geometric parameters for downstream processing and manufacturing. The model with such characteristic is not suitable for direct use in the visual visualization rendering in the VR field generally, especially when the amount of information of the parameterized model is large, it will cause the processing data volume of the visualization rendering to be huge and cannot be realized. The model established in the field of VR technology is a "polygon" model, which is much lighter than engineering CAD models. 3D modelling software commonly used in the field of virtual reality includes Unity3D,
Unreal Engine 4, 3DMax, P3D, etc [5]. However, there is no need to abandon the existing engineering parameterized model and use VR modelling software (such as Maya, 3ds Max, etc.) to redesign an exactly the same 3D model. You can use the existing engineering parameterized 3D model to transform it into a polygonal model.

In the development of civil aircraft, the three-dimensional modelling software is mainly CATIA. According to different application requirements, the light-weight methods of the model mainly include: conversion in professional software, conversion between professional software, and conversion in third-party software [6]. This article is based on the aircraft CATIA three-dimensional model. First, the software itself is converted into a format for preliminary lightening, and then the third-party professional software is used for further processing, and finally get a general polygon model used in the VR field.

Firstly, extract the relevant three-dimensional digital model in CATIA software, as shown in Figure 2.

![Figure 2. Aircraft cabin seat model made by CATIA software](image)

Secondly, the CATIA model is initially light weighted through special software (such as PiXYZ Studio), as shown in Figure 3.

![Figure 3. The model is processed in PiXYZ Studio](image)
Thirdly, the model is further processed in VR modeling software (such as 3ds Max, Maya), and the model is topologically made into a low model, as shown in Figure 4.

![Figure 4. The model is processed in the Maya software](image)

After modelling and simulating the digital airplane (CATIA digital model) with rendering software (such as 3ds Max, Maya), it also needs to go through the art links such as texture making, UV display, baking rendering, etc. before it finally forms a triangular surface model, generally fbx, obj and other file formats.

2.3. Interactive Interface Design

Interaction refers to the interaction between humans and machines, and the User Interface is the interactive interface between humans and machines. The transformation of the interactive mode runs through the entire history of the development of the IT industry. In 2007, Apple launched the iPhone, which also brought the computer into the era of mobile Internet touch screen interaction. The trend of human-computer interaction is more and more humane. In the 1980s, people had to be well trained to use the command line or write code, but now even children without any training can use smartphones or tablets. The interactive system designed in this article aims to achieve human-computer interaction through touch screens. I believe this interactive method will become the mainstream form of this field in the future.

The design of human-computer interaction functions in virtual reality scenes mainly includes three aspects. First is the interaction design of the primary and secondary relationship of the user interface; the second is the design of the interaction between the user interface and the user role; the third is the interaction design of the user interface and the virtual reality environment. In this paper, the design of the interactive interface mainly considers the user’s operating experience and the special environment of the aircraft scene, which must not only conform to the user’s operating habits, but also fully display the aircraft cabin environment. The specific UI interface of this article is shown in Figure 5 below, and the detailed control definitions are shown in Table 1.
Table 1. Formatting sections, subsections and subsubsections.

| Control Name                | Function Description                                                                 |
|-----------------------------|---------------------------------------------------------------------------------------|
| a  Scene Manipulation Mode Selection | Switch between "gravity sensing" control or "virtual joystick" control             |
| b  Pop-ups                  | Introduce the aircraft and its functions in the form of pop-up windows in the appropriate area |
| c  Virtual Joystick Left    | Control the "camera" to move forward, backward, left and right in the scene          |
| d  Virtual Joystick Right   | Control the "camera" to rotate within the scene                                       |
| e  Fast Scene Switching     | Switch between different aircraft cabin layouts and local area scene switching       |

Figure 5. Human-machine interface frame design

The human-machine interface framework can be understood as the expected goal of interface design. The realization of the specific human-machine interface mainly includes two steps:

First, use art software such as Photoshop and Illustrator to draw user interface images to grasp the visual style and overall artistic effect of the user interface. Here, corresponding design elements can be added for different audience groups or customers to form a customized style.

Second, the development of scene interaction functions. At present, mainstream 3D scene development software, such as UE4, Unity 3D, etc., provide modular scripts, which basically do not require third-party technology to realize scene interaction function development. For example, the blueprint function of UE4 engine, a set of visual programming system for developers to design scene interaction functions; another example is the Visual Studio programming environment in Unity 3D engine, which provides developers with original ecological program editing and debugging functions. This article uses the Unity 3D engine to develop, import the constructed 3D model and user interface into the Unity 3D engine, and design interactive functions through the Visual Studio programming environment in the engine.
2.4. Network Architecture

The expected application scenarios designed in this article include aviation exhibitions. Considering that the occasion may be dominated by large passenger flows, the system should not only have the ability to operate in a "stand-alone version", but also have the function of "online version", that is, the intelligence of a broad audience the terminal device uses the wireless network to access the background main program to realize the tour and experience of the aircraft virtual scene. Considering that video streaming in virtual reality scenes through wireless networks requires high bandwidth and low latency to get a better user experience, this system uses 5G network for performance test. The 5G network has not yet been fully established in China. The 5G network in this laboratory is a local area network, not a 5G public network. Integration with vertical industries is the main trend of 5G business innovation and an important growth point for the future mobile communication market [8].

WebRTC (Web Real-time Communication) is the abbreviation of web real-time communication. The core technology it provides includes audio and video collection, encoding and decoding, network transmission and display light functions. WebRTC also supports cross-platform operation [9]. The network communication architecture part of this article adopts the WebRTC technology based on the B/C/S architecture to realize the mutual transmission between the server, the client and the terminal browser through the wireless network (It is recommended to use a 5G network with high bandwidth and low latency).

Figure 6. Human-machine interface frame design

Different from the traditional B/S or C/S data transmission network architecture, this article is based on WebRTC technology and uses the B/C/S architecture. In this architecture, shown in figure 6, a host is used as both Server and Client, and the user terminal is defined as Browser. The user only needs a mobile terminal (tablet or mobile phone, etc.) equipped with a browser to connect to the background procedures. The procedures are fully open.

3. Key Technology

The key technical difficulties in this application scenario include several aspects. First, to convert the existing 3D engineering model of the aircraft into a polygonal model that can be used in VR, so as to solve the problem of smooth user experience and no stuttering when the aircraft is rendered in real time. The second is to solve the problem of multi-user online interactive access.

For the first question, the core is to solve the problem of computer calculations. The aircraft’s CATIA digital modulus is large. If the aircraft’s CATIA digital model is directly imported into real-time rendering software (such as Unity 3D), it will cause the software to crash or fail to open the model, or the picture will freeze, which cannot achieve the expected effect. In order to solve this problem, this article adopts two methods: one is model lightweight; the other is levels of detail (LOD). Through the lightweight model, the number of faces of the part (MESH) can be reduced to a minimum without affecting the final rendering effect; Through the levels of detail (LOD), the objects in the camera are classified and rendered during the rendering operation, the most detailed rendering operation is performed on the objects near the camera, and the simple operation is performed on the objects far away.
from the camera. That is, "processing contours at a long distance, processing details at a short distance". Through the above two methods, the final picture can be realistic, smooth, and free of jams, and present the user with a High-fidelity virtual reality scene.

For the second question, the core is to solve the problem of fast and convenient user access. Taking into account the actual business scenarios of the aircraft, it is impossible to allocate a virtual reality glasses or high-performance PAD to each user, and it is also impossible to allow users to download APP programs through their personal mobile phones and then experience the virtual reality scenes. Therefore, there must be a convenient and quick access method. 5G high-speed network becomes the key core to solve this problem. The idea to solve this problem is to configure a high-performance computer in the background to serve as a network server and also to execute the "real-time rendering program" of virtual scenes. Users located all over the world can scan the QR code to enable the Web built-in mobile phone. Through the 5G network to access the "real-time rendering program" in the background.

4. Application Prospects

4.1. Aviation Exhibition
In traditional aviation exhibitions, shown in figure 7, aircraft manufacturers mainly display aircraft prototypes and aircraft models of various scales to customers. The advantages of this display method are obvious. The audience can experience the real machine in a tangible way. The disadvantage is that for exhibitors, it is mainly reflected in the huge development cost of the real machine, and the calculation and disassembly costs are also expensive.

Using the method in this article, multiple people can experience the virtual aircraft online at the same time, and travel around the aircraft in various areas online. Simply by taking out mobile phones or Pads, and scanning the codes, the on-site audience are able to enjoy the wonderful visual world. The high-definition rendering images are transmitted to the user terminal in real time via a high-speed network to realize online browsing and interaction.

![Figure 7. Scan aircraft model to access](image)

4.2. Aircraft Customization
Customer selection is an important part in the aircraft sales process, and it is also an important opportunity for airlines to shape their image and build reputation. Faced by numerous airlines, it is impossible for aircraft manufacturers to carry out selection work by displaying physical objects one by one, which greatly reduces the efficiency of selection work. Therefore, online virtual selection and even DIY self-selection are imperative. One of the application scenarios can be seen in the future, shown in figure 8, airline customers choose a piece of real fabric that is their satisfaction, and by scanning the QR code (or radio frequency technology, etc.), The complete effect of these fabrics in the cabin and on the seats can be generated on the phone screen, which will fully show the overall design of the cabin interior to realize human-computer interaction. Customers can also adjust the parameters of the selection items online to achieve their desirable results and finally determine the customized configuration.
5. Conclusion
In the field of civil aircraft development, traditional engineering digital models cannot be directly used for engineering remote evaluation and customer experience due to various reasons. To this end, this paper designs a user-oriented civil aircraft application scene, that includes two core parts, firstly is to convert the existing aircraft 3D engineering model into a polygonal model that can be used for VR rendering, and secondly is to realize the problem of multi-user online interactive access to virtual scenes via WebRTC technology. The system can build virtual reality scene for an aircraft based on the real 3D engineering digital model of the aircraft. The user accesses the aircraft virtual reality scene through the wireless network, and realizes real-time control and interactive operation of the scene. Through this system, customers can do engineering evaluation and experience evaluation during the whole process of aircraft product design, development and sales. This article proposes a novel idea of the innovative application of VR technology in the field of civil aviation manufacturing industry, which is highly applicable in the future.

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