Original Research Article

Research on the Construction of Flight Platform Based on VR Technology

*Haixiang Wang, Yin Li, Zhibin Ge, Yuming Wang, Zhili Song[*Corresponding Author]*

Guanghan Training College, Civil Aviation Flight University of China, Guanghan, Sichuan, 618307, China

Abstract: With the increasing demand for reform and innovation in flight training technology and the application and development of VR technology, this study aims to build a simulation flight training system platform based on virtual simulation technology. By taking advantage of efficiency and low cost, it effectively undertakes a part of the high-cost real aircraft and simulator training in flight training, thus promoting the goal of ensuring flight training safety and improving training quality. This paper elaborates on the design and construction of the platform from the perspectives of software and hardware, the application of the actual operating process, and the qualitative analysis of training effectiveness. It is not difficult to find that the flight training simulation technology based on VR technology is effective and feasible. The construction of this platform has also achieved certain results and has more diversified potential uses and development.

Keywords: Flight training technology reform; VR technology; Flight training platform

1. Background

According to the Civil Aviation Administration of China's "Guiding Opinions on Comprehensively Deepening the Reform of Flight Training in Transportation Airlines" (CAAC Letter [2019] No. 39), the reform of flight training should focus on promoting the quality and efficiency reform of flight training, building a new era of flight training system with Chinese characteristics, and shifting flight style construction and core competency development to the training stage. Ground practice, precise flying in the air, and simulator training as important means to improve flight training quality and enhance personnel style and core competency play an indispensable role. Virtual reality has three characteristics: immersion, interactivity, and imagination. According to the Ministry of Industry and Information Technology's "Guiding Opinions on Accelerating the Development of the Virtual Reality Industry" (MIIT Electronic [2018] No. 276), the research and introduction of "Virtual Reality +" and the construction of simulation training systems and platforms based on virtual simulation technology can to some extent efficiently and cost-effectively undertake the functions of real aircraft and simulator training, thus promoting the quality and efficiency reform of flight training and effectively innovating and optimizing the system and supporting technology of pilot training.

2. Platform Construction

2.1. Objectives

By establishing a high-precision model database of key elements in the flight training process, using internationally common virtual reality development engines to research and develop virtual reality dynamic scenes of flight training subjects and core safety risk management, and building a virtual simulation experimental system and platform for multi-person simultaneous scenario applications, the platform can achieve simulated flight training teaching, pre-flight training preparation, flight training process safety management skills training, and style education training, aiming to improve flight training efficiency, reduce training costs, ensure flight training safety. The flowchart is shown below:

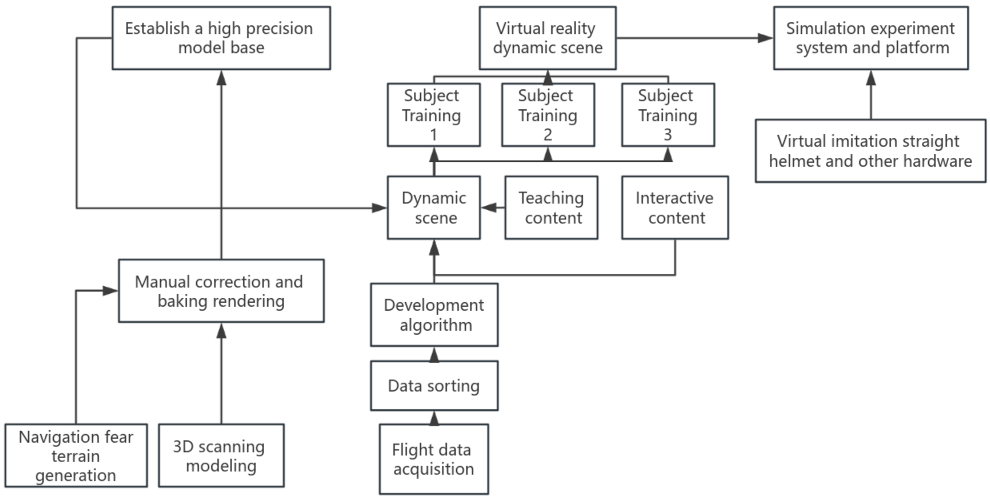

Figure 1. Platform Construction Flowchart.

2.2. Design and Construction

2.2.1. High-Precision Model Database

High-precision models of key elements in the flight training process are the foundation for the development of virtual simulation systems. By organizing the standard procedures and facilities of flight training and identifying the key elements necessary for flight training subjects and core safety risk management models, including training aircraft types, airport runways, ancillary airport buildings, and iconic landmarks in flight training airspace, high-precision models of each relevant element are constructed using high-precision 3D scanners for physical scanning, aerial photography data for terrain construction, and artificial baking rendering, forming a high-precision model database of key elements in the flight training process.

a) Aircraft High-Fidelity Modeling

Preliminary modeling is conducted using long-range laser scanning technology (with a high number of faces), followed by topological reconstruction using standardized 3D software (to reduce the number of faces). The texture images and materials of the model should maximize the use of UV distribution area to minimize the system resources occupied by images. The "texture baking" technique is employed to preserve the geometric features of complex 3D meshes into texture bitmap files, thus establishing high-fidelity models of aircraft. See **Figure 2** below:

b) Terrain Model

Utilizing Digital Elevation Models (DEM), which are created from limited elevation data, to digitally simulate the ground terrain (i.e., the digital representation of terrain surface morphology) and recreate real-world environmental scenes. See **Figure 3** below:

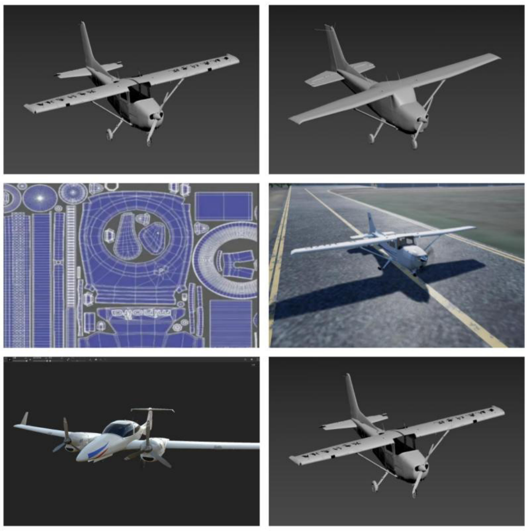

Figure 2. High-Fidelity Aircraft Modeling.

Figure 3. Digital Elevation Model (DEM).

2.2.2. Virtual Reality Dynamic Scenes

Based on a brand-new data engine, a virtual reality environment is constructed to recreate real flight scenes, forming a library of virtual reality dynamic scenes for flight training subjects and core safety risk management.

a) Hardware

Utilizing products from four different platforms: the Manus full-body positioning system, the Varjor high-precision head-mounted display, the Steam Vive VR Room spatial positioning system, and the Unreal Engine virtual development engine, fully leveraging the applicability, extensibility, implementability, and generality of the Internet of Things to achieve the integration and application of software and hardware for the project.

b) Customization of Platform Aircraft Models

The system comprises two different models of teaching aircraft. Modular management of aircraft models is achieved through object-oriented logic, and overall project management is handled through superior command layers to avoid strong coupling between function calls when implementing repetitive, similar logical functions. The triggering logic for both aircraft is processed in a single-threaded manner (single-threaded events), as shown in **Figure 4** below:

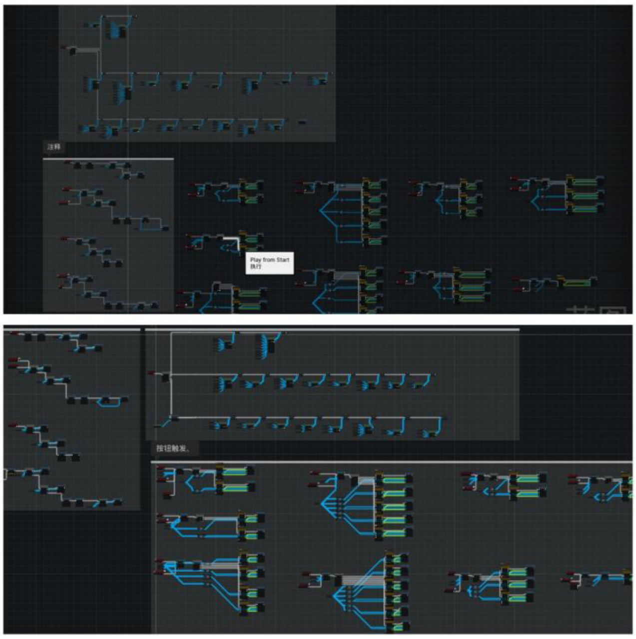

Figure 4. Single-threaded Processing.

c) Real-time Interaction in Immersive Virtual Scenes

Linking the Manus gloves in the virtual environment allows real-time feedback based on the hand movements of the trainees in the real world. Feedback from the hardware level reflects reality, while feedback from the software level is reflected in the virtual scene, making the feedback more direct and realistic, thus prompting trainees to engage in deep learning and memory of the knowledge points. See **Figure 5** below:

Figure 5. Virtual Scene Perspective.

The left panel is Actor BP_Plane Two Button, with each button corresponding to an independent function. The states generated by the functions are managed by the aircraft objects BP_SR20 and BP_Da402 respectively, and the panel itself does not participate in logic calculation.

3. Application of Flight Training Scenarios Based on the Platform

3.1. Scene Application

According to the overall curriculum outline for airline transport pilots, simulated scenario teaching plays an irreplaceable role, mostly implemented on training devices at present. Based on the outline courses FTD1 and

FTD2, training is conducted using the panoramic cockpit of the VR virtual reality system. The training scenarios for initial visual flight teaching are divided into four simple parts, as shown in **Figure 6** below:

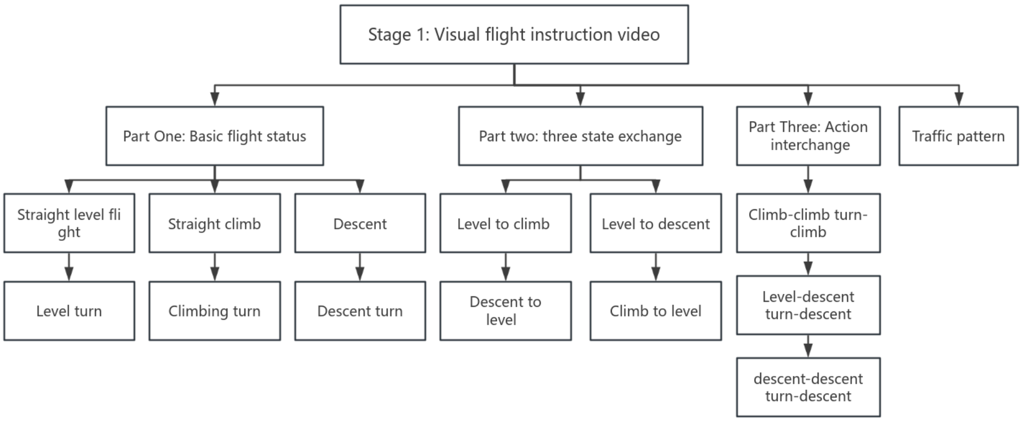

Figure 6. Visual Flight Teaching.

The simulated scenario experiment is divided into the following steps: first, no manipulation is involved, learning in a panoramic immersive cockpit; second, explanations and prompts regarding attention allocation are eliminated, consolidating the understanding of visual horizon gained in the first part; third, watching pre-recorded takeoff and landing route videos in VR for learning and establishing standard impressions; fourth, conducting flight training through VR in X-plane11; fifth, using control devices for flight training in the VR virtual reality environment.

Compared to the implementation of the four stages of traditional outline courses FTD1 and FTD2, it possesses more characteristics: first, using flight controls; second, eliminating explanations and prompts regarding attention allocation; third, completing autonomous flight under instructor monitoring; fourth, monitoring student eye gaze allocation and displaying it in real-time. Among these, the perspective is as shown in **Figure 7** below:

Figure 7. VR Flight Training Visual Scenarios.

3.2. Effectiveness Analysis

The effectiveness is evaluated through consultations with one flight instructor with 1000-2000 hours of flight experience, two flight instructors with 2000-3000 hours of flight experience, and three flight instructors with over

3000 hours of flight experience, analyzing the teaching of flight initiation, cockpit practice, and five-point (landing critical phase).

By establishing highly realistic and accurate scenes both inside and outside the aircraft, driven by SD card data, standard five-point flight attitudes are restored. Combining VR technology, students are immersed in the environment, facilitating repeated familiarization and practice of standard flight procedures and actions in a free, convenient, and fast manner. Meanwhile, teacher language prompts remind students of attention allocation and action points, allowing students to become familiar with flight scenes through visual rehearsals to instinctively respond to situations. The main effectiveness focuses on the following five aspects:

Firstly, with the aspect of environmental simulation, VR technology can simulate various landing scenarios, including different airports, weather conditions, wind directions, and speeds. Through visual and auditory effects in the virtual environment, students can feel the impact of different environments on five-point conditions and learn how to adapt and adjust flight skills.

Secondly, with the aspect of attitude and operation, students can learn correct landing attitudes and operational skills in the VR environment. Using control devices such as the trainer's control stick and pedals simulates real flight operations, allowing students to adjust the aircraft's attitude and control its descent rate angle to train technical elements of five-point flight and landing processes.

Thirdly, with the aspect of judgment and decision-making on five-point conditions and deviations, VR technology can simulate different final deviation scenarios, training deviation correction and decision-making. Students can learn how to make reasonable landing decisions and judgments in the virtual environment by observing factors such as runway length, surface conditions, wind speed, wind direction, and handling flight deviations.

Fourthly, with the aspect of emergency handling, VR technology can simulate emergencies such as mechanical damage, control surface/flap blockages, and engine shutdowns. Students can receive training in the virtual environment on how to handle emergency landing demands and related operating procedures.

Fifthly, with the aspect of flight recording and analysis, VR technology can record students' landing processes and flight trajectories on SD cards, providing real-time feedback and analysis. With this data, students can identify deficiencies and make improvements by reviewing their own five-point landing processes.

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About the author

Haixiang Wang(1995-),male, Jiaozuo, Henan, China, Han nationality. Third-grade pilot, Master degree, more than 2300 hours of safe flight, research direction: flight safety operation technology and flight human factors.

*Corresponding author:Zhili Song(1995-), male, Nantong, Jiangsu, China, Han nationality. Second-grade pilot, Master degree, more than 5200 hours of safe flight, research direction: flight safety operation technology and flight performance.

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