

# Design and Implementation of Unity-based Special Unmanned Vehicle Operating Simulator

Yiming Chen, Jiaxin Gao, Shiwang Gao, Chuanqi Li \*

Research and Development Center, Aerospace Internet of Things Technology Co Ltd, Beijing, China

\*Corresponding Author: [legendli0129@163.com](mailto:legendli0129@163.com)

---

## ABSTRACT

Special unmanned vehicles can replace personnel to perform military tasks with high risk coefficients, such as long-distance reconnaissance, guided irradiation, and weapons strikes. In order to ensure that the special unmanned vehicle can quickly and accurately complete the established task action, the operator should carry out a large number of trainings in advance for the task content, if the training is directly used in the early stage of the training to manipulate the training, which has the security risks, it's easy to increase the operator's psychological pressure, and the actual training site can't realistically restore the task scene, the training effect is also single. In view of the above problems, this paper designs a special unmanned vehicle control simulator, which enables the trainers to intuitively understand the task content and key points, and at the same time can control the unmanned vehicle in the virtual task environment to carry out the established task training and result review and analysis, so as to rapidly improve the control level of the trainers and ensure the successful completion of the established task.

## KEYWORDS

Operating Simulator; Special unmanned vehicle; Training software; Unity

---

## 1. INTRODUCTION

With the rapid development of the times, the trend of intelligent and unmanned demand in the field of special operations is becoming more and more obvious. Special unmanned vehicles have the functions of mobile deployment, rapid obstacle crossing, real-time information collection and return transmission, etc. The operator can remotely control the unmanned vehicle to perform the task, so that there is no need to enter the hazardous area to carry out the operation, which has a broad application prospect.

In order to ensure that the special unmanned vehicle can quickly and accurately complete the established task action, the operator not only needs to be trained in the early stage of learning the principle of the equipment and a long period of operation training, but also needs to be repeated and constantly practiced after having the basic operation ability. During this period, if all the training is carried out with actual equipment, there are many problems such as great difficulty in guaranteeing, high preparation requirements, limited number of equipment, etc., and it may occur some security risks such as make operational errors easily, equipment damage and so on [1].

At present, the commonly used unmanned vehicle training program is to combine the teaching materials with the actual equipment for equipment cognitive learning, and the second is to simulate the control training in the actual parking state. In this process, because of the inability to operate the

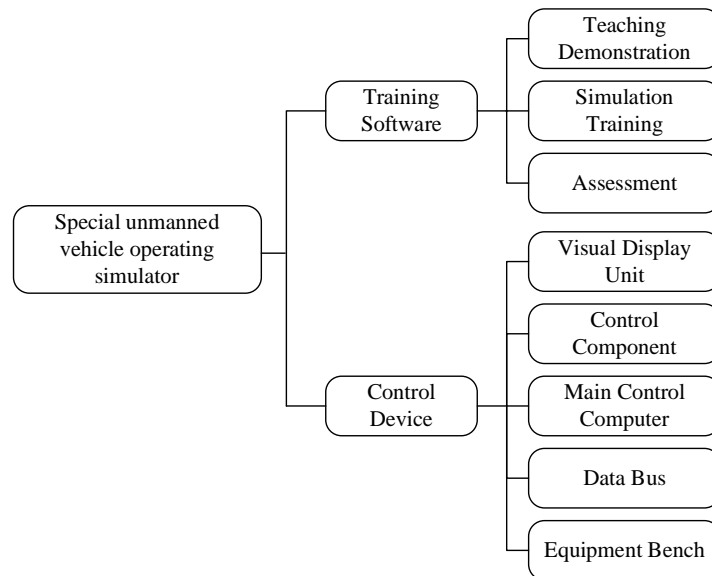
real equipment linkage, it is easy to cause a large difference between the simulation control and the real equipment control, which is not conducive to the rapid mastery of the equipment control methods by the trainers. In addition, the existing training assessment tools also exist standardization, lack of process and other issues, which affects the training effect of trainers.

For the above problems, in order to improve the training quality of special unmanned vehicles, this paper designs a special unmanned vehicle operating simulator. The system contains operating equipment and training software, and the operating equipment is designed semi-physically with reference to the actual installation, which minimizes the difference with the actual equipment and improves the sense of realism of the operation [2]. The training software is developed by Unity software, SolidWorks and 3Ds Max. Trainers can intuitively understand the content and key points of the mission through the simulator, and at the same time, they can control the unmanned vehicle in the virtual mission environment to carry out the established mission training and review and analyze the results, so as to rapidly improve the control level of the trainers, and ensure the successful completion of the established mission.

## 2. OVERALL DESIGN

### 2.1. Composition Structure

The special unmanned vehicle control simulator adopts a technical solution that combines digital models of the equipment with semi-physical control devices, enabling the simulation of the unmanned vehicle's functions and providing a training environment for operators. The simulator is mainly composed of two parts: training software and control equipment, as shown in Figure 1.



**Figure 1.** The composition of the simulator

The training software includes three functional modules: teaching demonstration, simulation training, and assessment evaluation. These modules are primarily used for self-learning and control training by trainees, helping them to improve their control skills and master key operational points [3]. The control equipment consists of a simulation module, control components, a main control computer, and equipment racks. It is mainly used for information interaction between the operator and the training software, providing control feedback that is highly consistent with the actual equipment.

To ensure that the control experience and visual effects during simulated training are consistent with those of the actual equipment, the layout of the control devices and the visual display units in the system are designed strictly according to the real equipment setup. Additionally, to ensure the

authenticity of the control experience, all types of joysticks in the control components are designed using semi-physical devices.

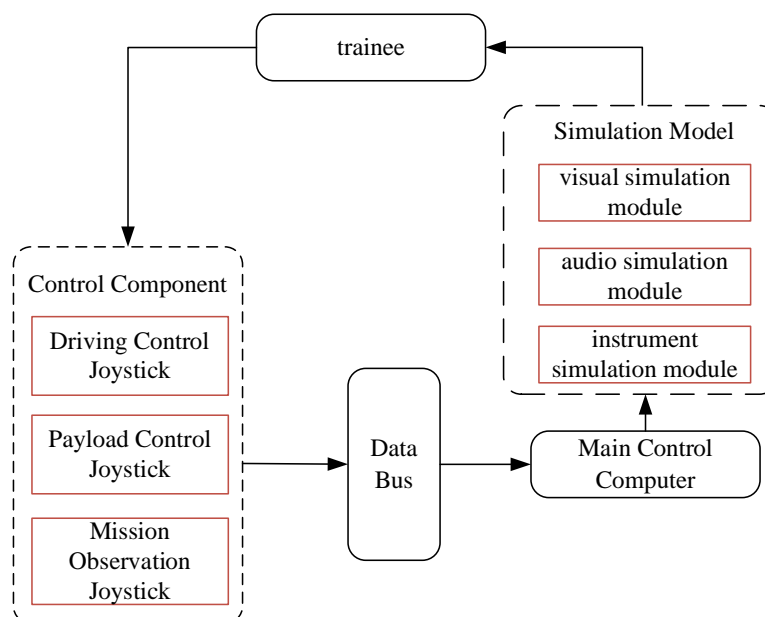


**Figure 2.** Unmanned Vehicle Operating Simulator

## 2.2. Working Principle

During the control simulation process, the control console governs the operational status of the entire system. The simulator utilizes input devices (such as the driving control joystick, payload control joystick, and mission observation joystick) to collect the operator's control signals in real-time. It then calculates the unmanned vehicle's performance, collision status, and other factors. The computed driving status information is transmitted via the data bus to various simulation modules, including the visual simulation module, audio simulation module, and instrument simulation module.

The visual simulation module dynamically invokes 3D visual models (including mission scene models and unmanned vehicle models) to generate and drive 3D scenes, which are then displayed on the visual display units [3]. The audio simulation module retrieves audio assets, synthesizes audio signals, and drives them to the audio output devices. The instrument simulation module receives vehicle data and updates the virtual instruments in real-time.



**Figure 3.** Interaction Diagram

Trainees use the visual and auditory information to control the unmanned vehicle model within the simulation training software, effectively performing driving and operational tasks. This creates a

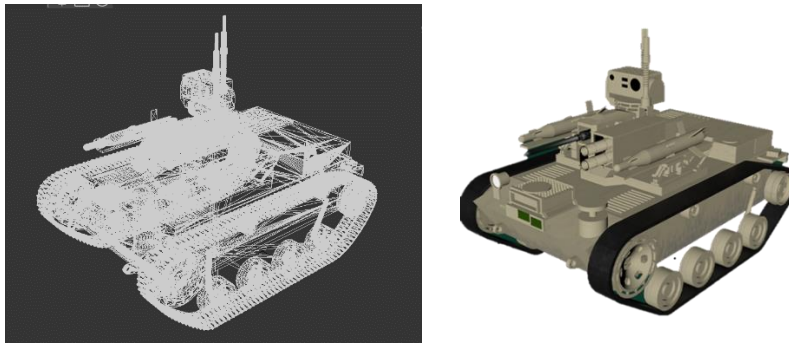
closed-loop human-in-the-loop simulation. The working principle of the system is illustrated in the following diagram.

### 3. IMPLEMENTATION OF TRAINING SOFTWARE

#### 3.1. Model Creation and Rendering

The 3D model of the special unmanned vehicle in the system is designed with reference to the actual equipment and is divided into three parts: the chassis system, reconnaissance system, and operational system. Each part is modeled using SolidWorks, and the models are exported in STEP format. These STEP models are then imported into 3ds Max for coordinate adjustment and texture mapping, followed by rendering to meet the requirements for importation into Unity 3D [4].

To ensure smooth and stable operation of the software, the models need to be optimized during processing. This optimization involves reducing the number of polygons, compressing textures, and applying Level of Detail (LOD) techniques. The optimized models have a higher precision than LOD level 3, with the high-fidelity models consisting of no fewer than 5000 polygons.



**Figure 4.** 3D wireframe model and 3D rendering model

The appearance textures of the models are based on the actual equipment, with detailed adjustments made for reflections, refractions, and other aspects. The final rendered effect is shown in the accompanying figure.

#### 3.2. Scene Construction

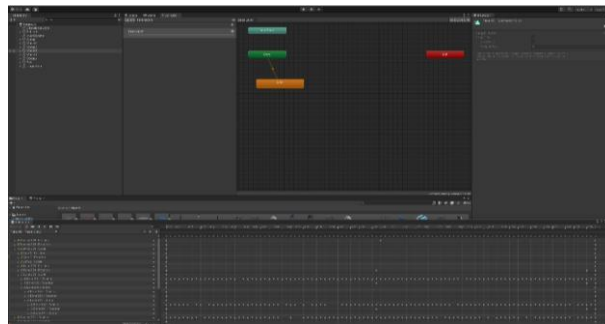
The training scene is constructed in Unity 3D and includes terrain, topography, weather effects, light sources, and scene object models. The Terrain component in Unity 3D is used to edit the terrain, the Skybox component is employed to adjust the sky, the Particle System is utilized to simulate weather phenomena, and the Mesh Renderer ensures the correct rendering of models. The scene construction results are shown in the accompanying figure [5].



**Figure 5.** Scene rendering effect

### 3.3. Animation and Audio-Visual Components

In the simulation system, to closely mimic the operational experience of the actual equipment, the model animations are designed based on the real equipment's movements. The animations are divided into three parts: the movement of the chassis system, the horizontal and vertical rotation of the reconnaissance system, and the rotation of the operation system. The Animator component is used to set animation frames, adjusting the position and angle of objects to simulate actual movement and rotation scenes [6]. The main camera, as a child object of the unmanned vehicle model, uses the Transform component to adjust its position and rotation, ensuring that the perspective aligns with the real equipment. Additionally, a monitoring camera is set up to provide operators with multi-angle views, enhancing the control experience [7]. The Audio Source and Audio Listener components simulate target sounds, allowing operators to quickly locate targets during simulated training by combining visual and auditory information [8].



**Figure 6.** Animation editing interface

## 4. SYSTEM DEPLOYMENT AND TESTING

To evaluate the training effectiveness of the simulator, testing was conducted after the completion of the training software development. The developed training software was deployed on the main control computer, which is configured as follows.

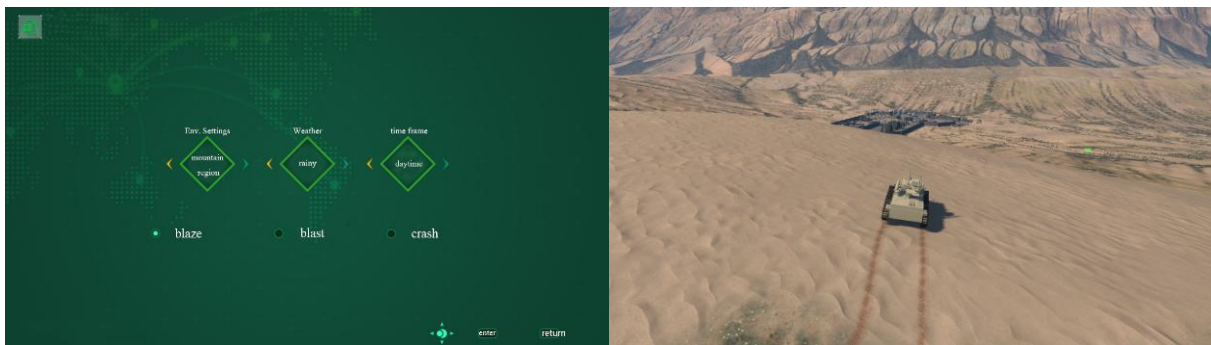
**Table 1.** The configuration of the main control computer

No.	Name	Parameter
1	OS Version	Windows 10 64-bit
2	System RAM	16GB (2×8GB)
3	CPU Core	Intel CORE i5-13400
4	CPU Speeds	Turbo 3.80GHz
5	Video Card	GeForce RTX 2080
6	Hard Disk	500GB

After the software deployment was completed, the special unmanned vehicle control simulator was started, and the functionalities and display effects of the teaching demonstration, simulation training, and assessment evaluation modules were tested. The results are as follows.



**Figure 7.** Teaching Demonstration



**Figure 8.** Simulation Training



**Figure 9.** Score settlement interface

The testing results indicate that the developed training software effectively demonstrates the structure, functions, and working principles of the equipment through the teaching demonstration module, with smooth animation of the 3D models. In the simulation training module, users can configure the training environment, weather, and operational time periods, and control the unmanned vehicle model in the software to perform corresponding actions such as driving, gimbal rotation, and operational device movement using the control components. After training, the assessment and evaluation module judges the correctness of the training process and the accuracy of the control, records the operator's mistakes, and provides a comprehensive score for the operational performance.

## 5. CONCLUSION

Special unmanned vehicles can perform high-risk military tasks that would otherwise endanger personnel, offering extensive application prospects. However, current real-world training for special unmanned vehicles faces issues such as poor safety, inability to realistically recreate task scenarios, and limited training effectiveness. To address these issues, this paper designs a Unity-based special

unmanned vehicle control simulator, outlines its components, and implements and tests the training software. The testing results show that the special unmanned vehicle control simulator accurately simulates task scenarios for unmanned vehicle operation training. Additionally, the assessment and evaluation features enhance operators' skills, significantly optimizing the training effectiveness of special unmanned vehicles. This simulator addresses the shortcomings of real-world training, reduces training costs, and holds significant practical value and promising prospects.

## REFERENCES

- [1] Song, G., & Chen, T. (2013). Simulation Training Platform for Fire Control System of Certain Type Long-Range Rocket Gun. *Ordnance Industry Automation*, 32(3), 21–23.
- [2] Kou, C., Sun, S.-y., Wang, C.-p., & Fu, Q. (2011). Design and realization of simulation experimental platform for self-propelled anti-aircraft gun. *Fire Control & Command Control*, 36(10), 182–185.
- [3] Wang, P., Li, H., Liu, X., & Yang, X. (2016). Software Design and Development of Mine Laying Simulator on Rocket Based on Unity 3D. *Machine Building & Automation*, 46(06), 137–141+144.
- [4] Xu, J., Cui, P., Wen, J., & Zhou, X. (2022). Virtual Training System Design of Terminal Guided Projectile Fire Preparation Based on 3DSMAX and Unity3D. *Journal of Ordnance Equipment Engineering*, 42(07), 30–34.
- [5] Yang, M., & Hu, Y. (2020). Design and Development of Core Drill Simulation Operating System Based on Unity 3D. *Nonferrous Metals Engineering*, 10(09), 117–121.
- [6] Li, S., Zhang, X., Wang, Y., & Liu, J. (2000). Simulation & Training System of Ship Engine Based on Virtual Reality. *Journal of System Simulation*, 12(3), 193–196.
- [7] Hou, X., Liu, W., & Zhang, H. (2015). Realtime Sky Background Scene Image Simulation in Helicopter Flight Simulator. *Computer Engineering and Design*, 36(03), 742–746.
- [8] Yu Z Jinxing, Li H, Han Z, Yang X (2021). Design of Simulation Maintenance Training Platform for Electro-Hydraulic System Based on Hardware-In-The-Loop Simulation. *MECHANICAL MANAGEMENT AND DEVELOPMENT*, 36 (09), 214-216