Design of optical sighting telescope training system based on simulated target

Menglei Li¹, Yingjiao Rong² Shirui Wang¹, Yuchen Wang¹, and Ping Sun*¹

¹CSSC Ocean Exploration Technology Institute Co., Ltd. Wuxi, Jiangsu, 214035, China
²Science and Technology on Near-Surface Detection Laboratory, Wuxi, Jiangsu, 214135, China
*Corresponding author’s e-mail: csscoeti@csscoeti.com

Abstract. In order to solve the practical operation training problem of an optical sighting telescope in certain weapon system, the application research of simulated target technology is carried out. According to the tactical and technical characteristics of sight and battlefield target, based on the embedded simulation framework, a series of simulation target technologies, such as constructing the optical characteristic model of target, fitting the target trajectory, encapsulating the characteristic information of target in the typical scene, are used to explore the technical route of actual combat training relying on actual equipment and simulation target, and realize the training scene and its model. The application results show that the method is feasible.

1. Introduction
Periscope optical sighting telescope is a kind of observation equipment used by shooters, which is mainly used for shooting in night. The shooter uses the equipment to complete the environment reconnaissance and target searching tasks, and aims at the specific target before shooting. By analyzing the training status of periscope optical sighting telescope, we can see that there are two common training methods under current conditions [1]: one is to rely on the software simulation environment or simulation training device to carry out simulation training, which is mainly used in the early stage of operator training, in order to assist the operator to be familiar with the basic principles and use methods of equipment; the other is to rely entirely on real equipment. These two modes are difficult to meet the needs of actual combat training. It is urgent to explore new technologies and methods, focus on providing scenes and objectives close to the actual use of weapons and equipment, rely on real equipment to carry out targeted and repetitive training, and summarize training experience and evaluate training effect.

Simulation target technology provides a useful way to realize the above functions. This technology is one of the branches of computer simulation technology in training application. Based on computer algorithm reconstruction of target characteristics and computer graphics theory, the target characteristics defined by algorithm, target motion defined by dynamics and field of view defined by spatial model are established in virtual space, and all the above elements are classified into real data structure to standardize, select the appropriate electrical signal interface protocol, and seamlessly generate the simulation target close to the actual situation of training on the actual equipment, so as to realize the content standardization, effect evaluation and use case recurrence of the actual combat training.
Aiming at the problems existing in the equipment training of periscope optical sighting telescope, this paper explores the systematic research on the application of simulated target technology to construct the actual combat training conditions. Based on the embedded simulation framework, a series of key technologies of simulation target, such as constructing the optical characteristic model of the target, fitting the target trajectory, encapsulating the characteristic information of the target in the typical scene, are explored to carry out the actual combat training based on the actual equipment and simulation target, so as to realize the seamless link between the training scene and the simulation target and the periscope optical aiming equipment. Finally, the technical application verification is carried out based on the equipment.

2. System framework design

Embedded simulation technology is to embed simulation system in equipment system in physical structure and function [2]. The simulation system in the framework needs to be used together with the actual equipment to realize the training function. Equipment provides real interactive operation device, and simulation provides environment simulation, target generation and other external input information. The two complement each other, which is the realization of virtual simulation on the actual equipment, or the implementation of virtual simulation on the actual equipment.

3. System hardware design

Select the vkboard Board [3] with Ti omap4460 chip as the core as the embedded hardware platform of the system, as shown in figure 2. The platform provides low-power arm architecture processor and 400MHz GPU coprocessor, which is widely used in embedded image signal processing system.

The complete system hardware block diagram is shown in figure 3. The vkboard board is the core hardware to realize the target simulation. It is installed in the equipment signal processing chassis and receives the scene setting instructions sent by the terminal through the wireless link. The terminal adopts rugged laptop shelf products, and receives all kinds of state information of vkboard through wireless communication link to form effect evaluation results. Vkboard achieves the function of acquiring
equipment can bus data through CAN bus interface, so as to obtain operation information. The function of target driver is realized through the interface of kv2-csi and the simulation processor.

**Figure 3. Block diagram of system hardware composition.**

### 4. Key technologies

As a kind of observation and aiming device, periscope optical sighting telescope plays a role of target detection in weapon system. By manually controlling the pitching, rotation and focal length adjustment mechanism of the sight, the operator puts the observation focus on a target in the field of vision, and provides the key parameters information about the target's distance, angle and so on for further shooting. The key to the development of simulation training system is the simulation target generation technology. Through the analysis, we can see that in the actual situation, there will be one or more targets in the field of vision of the sight. In addition to the motion trajectory and appearance characteristics, each target will also show "behaviour" constrained by the time axis and represented by characteristic events, such as acceleration and deceleration, parking, turning and other state changes. In order to simulate these behaviours, features, motion states and environments, it is necessary to model the space environment and target features within the field of view of the operation pointing angle of the periscope. Based on the model, the optical characteristics and motion characteristics are simulated; furthermore, the independent characteristics are combined into a spatiotemporal logical whole by using the target encapsulation technology, and finally a training case is generated by combining the environment characteristics. The case contains the field of view image of the target state information and its motion characteristics, which is used to train the operator from search and discovery to recognition and acquisition, and then to tracking, aiming and locking the target. The whole process of action.

#### 4.1. Construction of target 3D model

According to the target features, it can be divided into rigid parts and non rigid features to model. The rigid part constructs the target 3D model through simple geometric elements such as vertices and polygons in equal proportion [4]. The non rigid features such as smoke and plume are constructed by particle system. The available software of the former includes: UG, Solidworks, AutoCAD and so on. The common methods to solve this problem include: reducing the number of faces as much as possible, using different granularity models to describe objects at different distances, carefully selecting materials and mapping applications.

#### 4.2. Target optical characteristics processing

In general, the optical imaging methods commonly used in weapon systems include visible light imaging, infrared imaging, microwave imaging, low light level night vision and laser imaging technology which has been greatly developed in recent years. Taking the visible light target as an example, after constructing the 3D model of the target, in order to ensure the authenticity, texture mapping is used to process its appearance, as shown in figure 4a. By calculating we will get a large database, in which the radiation characteristics of typical surface emission and atmospheric parameters are collected. After radiation calculation for each pixel of the target, the infrared simulation effect picture can be obtained, as shown in figure 4b.
4.3. Construction of target motion characteristics

Motion is the most typical characteristic of target, and it is also the focus of simulation. Motion simulation is based on the principle of Newton mechanics. It can simulate the motion of the target from different angles, such as kinematics, vibration and so on. Taking the ground target as an example, the motion of the object on the plane can be divided into axial motion and lateral motion [5-6]. The former refers to the translation along the longitudinal axis of the object, while the latter refers to the tilting and turning characteristics of the object. The modelling of lateral dynamics is shown in figure 5. Figure 5a is a horizontal dynamic top view of the driving carrier, and fig 5b is a horizontal dynamic front view.

The origin of the absolute coordinate system is the intersection of the plane perpendicular to the road surface where the centre of gravity of the carrier is located and the central line. The x-axis is the tangent direction of the central line, and the y-axis is perpendicular to the Z-axis and in the same horizontal plane with the x-axis. The origin of the carrier coordinate system is the centre of gravity, the X axis is the longitudinal axis of the body, that is, the forward direction, and the Y axis is perpendicular to the longitudinal axis of the body and in the same horizontal plane with it. There is a little deviation between the forward direction and the actual speed direction, which is due to the rolling resistance and slope resistance of the carrier caused by the ground type and longitudinal slope during the forward process.

4.4. Target encapsulation

The purpose of object encapsulation is to make the separated objects, scenes, driving equations, graphics and textures logically integrate into a whole. Information must meet the transmission format requirements of periscope optical sighting telescope before it can be used to drive actual equipment; the first step of packaging is information standardization processing [7], which is based on time and space "alignment", that is, the superposition, translation and scaling of centroid motion curve and target motion attitude relative to time axis, and the coordinate transformation, data structure and format relative to space reference coordinate system Then, the relative time of feature events is aligned on the time axis, and the target integrated feature model is encapsulated. The data structure of the target after encapsulation is shown in figure. 6.
4.5. **Training scenario generation technology**

The generation of training case is the central problem to be solved by the scene/situation control engine. Considering the constraints of tactics and technology, the core influencing factors of the generation of training case for Periscope equipment include: lighting conditions, natural environment (fog, rain, cloud, etc.), concealed position of shooter/operator, output of Intelligence Command and control system, number of targets and threat degree. The sensor based on optical/electrical signal conversion is the initial source of information. When generating training cases, it is necessary to integrate these factors in a comprehensive way and simulate them separately. The software design follows the general standard model, which fully reflects the universality and computer resource friendliness. The balance between time and storage space is used to seek the global optimum.

Geographic coordinate system is the reference coordinate system to build the simulation area of training scene; digital map technology is used to map the three-dimensional solid model to geographic coordinate system; the centre of mass motion and attitude motion of the object are driven by dynamic equations, in order to increase the authenticity, the driving equations such as elastic vibration can be further established; the absolute time information is given by the simulation clock. Feature events are superimposed in the scene to imitate all elements in the training case.

5. **System test and verification**

Experimental method is used to verify the effectiveness of the above design system and framework. Based on a certain type of air defence weapon system, the verification of periscope optical sighting telescope is carried out. The required software preparation includes: visible light imaging software, target dynamics software with limited manoeuvrability in two-dimensional space, texture generation and rendering, training configuration control software, etc. After the software is ready, the scene situation control engine is used to realize heterogeneous data drive. According to the actual workflow, the operation parameters are set. The signal flow, control flow and data flow of the whole process are completely consistent with the actual goal. Specifically, as shown in figure 7, the driving information and environmental factors given by the target model according to the scene control are converted into the simulation scene, which is the display content in the field of view of the optical sighting telescope given in the training.

The scene is converted into digital signal according to the definition of equipment signal, instead of the FPGA output signal in the optical CCD module, and sent to the follow-up signal processing circuit. The field of view of the optical sighting telescope is the above scene content, which realizes the replacement of the real training environment and training target with the simulation scene. Methods the application results show that the method is flexible, such as daily individual training, equipment training assessment, equipments cooperation training and so on. It has the advantages of high authenticity of scene reproduction, repeatability of training cases and controllable cost.
6. Summary

Based on the analysis of the problems in the practical training of periscope optical sighting telescope, the application of simulated target technology in the practical training system of periscope optical sighting telescope is studied. According to the tactical and technical characteristics of periscope optical sighting telescope equipment and battlefield target characteristics, based on the embedded simulation framework, a series of simulation target technologies, such as building target optical characteristic model, fitting target trajectory, encapsulating target characteristic information in typical scenes, are used to explore the technical route of actual combat training relying on actual equipment and simulation target, and realize the training. The scene and the simulated target are seamlessly linked with the periscope optical sighting telescope equipment, and the experimental case is fully verified in the actual equipment. The test results of experimental cases show that the system designed in this paper can better solve the problem of simulation scene authenticity and consistency, and can be further applied to scenario generation, operational deduction, effectiveness evaluation and other comprehensive scenarios, with high economic advantages.

Acknowledgments

This project was supported by Stable Foundation Project of the Science and Technology on Near-Surface Detection Laboratory with funding number TCGZ2020B001.

References

[1] Zhou X. S. (2019) Research on practical training method of optical measurement equipment based on simulated target. Journal of Jilin University, 37(2): 194–201.
[2] Liu Y. H., Lin P. (2010) Research on embedded simulation technology and its military application. Military operations research and systems engineering, 24(4): 29–34.
[3] Vincent. G. K.. (2009) VKboard Sheet. https://www.omappedia.org/vkboarddatasheet.
[4] Yang S. (2017) CCD image simulation system of photoelectric theodolite based on Vega Prime, Infrared, 38(10): 25–30.
[5] Li, H. L. (2014) Dynamics. China Machine Press, Beijing.
[6] Dong J., Gong X. (2016) Modeling and Simulation of plume radiation intensity with line of sight, Journal of Changchun University of Technology, 39(3): 73–77.
[7] Dickmanns, E. D. (1984) The seeing passenger car Vstar. In: Proc. IEEE Symposium on Intelligent Vehicles. New York. pp. 68–73.