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Virtual Range Training Based on Virtual Reality*

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***Abstract*—According to the virtual reality technology, the development of simulation system and the actual needs of shooting training, it is necessary to analyze the simulation training system and establish virtual shooting range, determine the basic framework of virtual shooting training system and design the basic functions of equipment replacement, shooting effect and material feedback, as well as functions of weapon assembly, research and development and action matching. The paper has described part of the functions, introduced the key factors and technologies of building virtual range and prospected the application modes of simulation training system in future life and military training.**

Keywords—virtual reality; Unity3D; human-computer interaction; military training; shooting range

I. INTRODUCTION

VR is a highly realistic human-computer interaction technology that simulates human visual, auditory, olfactory, tactile and force senses and other perceptions. It is a new comprehensive information technology at the end of the 20th century. It integrates digital image processing, computer graphics, multimedia technology, sensor technology, artificial intelligence, network technology and other technologies into one. With its powerful three-dimensional spatial expression ability, it brings people immersive experience, greatly promotes the development of computer technology, and makes a qualitative leap in the simulation training system. VR theory and technology are widely used in many fields, such as military, aviation, aerospace, navigation, education, medical treatment, commercial design, manufacturing, art, entertainment and archaeology. It has brought enormous social, economic and military benefits. It is a new tool with huge potential, temptation of prospects and enlargement of wisdom.

In traditional military training, shooting training is a high-cost, high-risk, environmental-damage military item restricted by time, space, climate and other conditions. In addition, due to limited conditions, many practical training is almost impossible to achieve. In contrast, simulation training based on virtual reality technology cannot only save training time and cost, but also reduce the loss of human and material resources. It also greatly improves the safety and comprehensiveness of training.

II. THE DEVELOPMENT STATUS AND CHARACTERISTICS OF VIRTUAL REALITY TECHNOLOGY IN CHINA AND FOREIGN COUNTRIES

A. The Development Status of Virtual Reality Technology

With the sustainable development of science and technology and industrial ecology, China's virtual reality industry is stepping into a period of rapid growth. China's virtual reality has made some progress in the fields of artificial intelligence, 5G communication, emerging reality and other fields. Our government actively promulgates relevant policies to support industrial development and education informatization, especially the development and application of virtual simulation training system. The United States is the birthplace of VR technology that is mainly used in three aspects, education, skills training and emotional experience. It has a great reference for the development of the application technology of this industry in our country. “Virtual Reality+" releases new vitality to traditional industries. It is combined with film and television, education, scientific research, military, cultural relics protection, digital exhibition hall and so on. Through his immersive experience,

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virtual reality technology is rapidly expanded to different fields.

Overseas research: In the mid-1990s, the US military spent $1 billion to establish a close-combat tactical training system, which connects troops distributed in different geographical locations, military academies at all levels and many combat simulation training simulators, and establishes a comprehensive virtual combat simulation system, which can connect about 65 workstations from Korea to Europe. Soldiers of all kinds of weapons can conduct dynamic military exercises in virtual combat environments. The build-in close-combat tactical systems assemble tactical training systems at all levels of the United States with the help of local area networks, wide area networks and long-range communication networks.

Domestic research: VR training system is developed toward command, tactics and other training needs. 28 research laboratories of China Electrical Technology released "VR training system for smart commando team". It provides red-blue confrontation, post-war reexamination, and multi-person immersive training at the same time. It realizes the coordination of guidance, command and combat, and helps the army to improve its combat capability rapidly.

B. *Characteristics of Virtual Reality Technology*

1) Immersive characteristic: Users are totally in the virtual world. Users can get many kinds of sensory feedback through the experience of virtual reality devices, so that they can get a better experience.

2) Interactivity: It refers to the user's maneuverability of the object in the simulated environment and the natural degree of feedback from the environment. With the help of virtual reality devices, users can get the same sensory feedback as in the real world. At the same time, this kind of interaction mode is more in line with ergonomics.

3) Imagination: The virtual environment constructed by human imagination provides a new way of thinking and methods for some real world problems that are not easy to solve.

III. Application of Virtual Reality Technology in Military Field and Shooting Training

All along, countries have attached great importance to military training. With the evolution of national events, more and more countries have invested a lot of research and development funds, time and energy in the field of VR military simulation training. Generally speaking, military training is not only expensive and resource-consuming, but also limited by various conditions such as the environment, and cannot better formulate training plans for all-round and multi-angle training. Therefore, the economy of VR makes it one of the important components of simulation technology.

In fact, VR has long been integrated into the military field. The Chairman of the Joint Chiefs of Staff of the United States has pointed out on many occasions that "it is an important goal of the modernization of the United States Army in the 21st century to strengthen the military through the use of advanced simulation systems and virtual reality technology". According to statistics, the funds for the development of simulation training equipment and kitchen boards of the United States Army are more than doubled every five years. Since 2012, the U.S. military has been using exclusive VR hardware and software for simulation training, including war, combat and other military training. This kind of training method can help soldiers train in various dangerous situations in a more economical way. This kind of development and research will also be planned into the "National Key R&D Program" in China.

VR can be used not only in actual combat simulation, but also in military medical training, conscription activities, submarine simulator, virtual skydiving training system, military weapon detection and so on. Even VR psychotherapy is used to treat soldiers injured in war, leaving psychological shadow after difficult battles or unable to adapt to stress disorder diseases under high-intensity training. Through VR technology, absolute security state can be simulated to entirety enables these soldiers with psychological problems to gradually adapt to the problems of war and relieve their mental illness.

IV. Structure Description of Virtual Range System

Based on the development of Unity3D engine, the system provides equipment recognition, shooting training and other functions on the premise of making simulation training with human-computer interaction as the core. Through linking VR equipment and matching simulation firearms, shooting exercises can be carried out in various target modes and different environments. According to the data of each practice, more effective training methods can be analyzed, sorted out and set, and data settings of virtual range can be adjusted according to demands of trainees timely. Such a system reduces the limitation of hardware conditions of shooting training, solves the cost problem of training. It can be applied not only to soldiers' shooting training, but also to entertainment scenes. (See "Fig. 1")

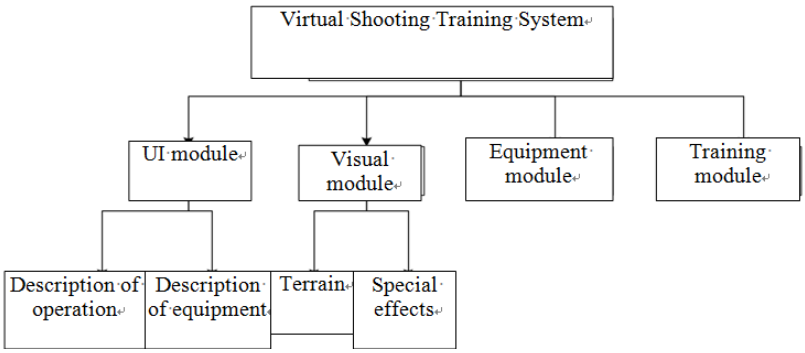

Fig. 1. Virtual Shooting Training System.

A. Generation of Virtual Range Environment

1) Indoor range training: At the beginning of training, indoor shooting training can be carried out to connect simulation guns, sensor devices and infrared devices to simulate more realistic gun situation.

Firstly, the user's shooting/combat actions can be trained and tested whether they are standard by wearing sensor devices and sensory interaction devices. Then, the user's reaction ability can be trained by designing different target forms. The user's aiming ability and basic shooting ability can be trained through basic target (static target). The advanced shooting ability can be trained by mobile target by modifying the parameters such as size, distance, height, speed and moving mode. (See "Fig. 2")

Fig. 2. Virtual Indoor Range Environment.

2) Outdoor range training: In the real world, due to the limitation of funds and other conditions, the form of shooting training will also be limited. Virtual Range outdoor training will not only integrate various terrains, including land, sea and other modes, set up various obstacles and available resources in each scene, but also differentiate different arms for appropriate training. The system can also control weather patterns and sunshine intensity in real-time, increase the variability of the environment, and facilitate the training of soldiers' response ability in different environments and psychological quality in sudden situations.

It is necessary to collect a large number of materials, hardness, resistance coefficient and other parameters of trees, stones and other objects in real life, systematically analyze and calculate the physical effects of these objects after hitting by bullets, artillery shells. The more realistic visual effects can be achieved through adjusting particle parameters according to calculation results. After detailed data analysis, the 3D technical background can be established, including battlefield, weapons and other highly realistic models. Based on virtual reality technology, the three-dimensional combat environment can be simulated to achieve vivid visual, auditory and tactile effects, thus enabling soldiers to complete many real battle trainings indoors, from which to practice combat actions and summarize tactical essentials.

In low-risk, low-cost small environment, it can help train soldiers' the actual tactical ability and on-site rapid response, psychological endurance and battlefield viability, improve combat skills and training efficiency.

B. Visual and Auditory Senses and Special Effects

1) Material feedback: It is necessary to adjust the particle parameters to simulate the shooting effect of firearms, show real hit feedback, and set different materials and corresponding effects, including the collision of bullets with walls, ground or metal targets, to make the experience more real.

The core code, as shown in "Fig. 3", can be achieved by function of material selection:

```
public class ImpactInfo
{
    public MaterialType.MaterialTypeEnum MaterialType;
    public GameObject ImpactEffect;
}

GameObject GetImpactEffect(GameObject impactedGameObject)
{
    var materialType = impactedGameObject.GetComponent<MaterialType>();
    if (materialType == null)
        return null;
    foreach (var impactInfo in ImpactElemets)
    {
        if (impactInfo.MaterialType == materialType.TypeOfMaterial)
            return impactInfo.ImpactEffect;
    }
        return null;
```

Fig. 3. Core code.

Particle system represents the technology of simulating some specific fuzzy phenomena in three-dimensional computer graphics. By adjusting the parameters of particles (life cycle, size, color, position, speed, etc.), the effects of smoke, flame, rain and snow can be realized. The special effects of material feedback hitting different material objects is realized by adjusting particle attributes, including wood, stone and so on.

2) Device connection: The recoil force of firearms can be realized by connecting simulation firearms equipment, and the real pain can be experienced by connecting induction equipment. The recording, playback and intelligent analysis of simulated live weapon firing in the aiming and tracking process can be realized by connecting infrared equipment, and appropriate plans can be made to improve the training quality. In order to solve the problem that in the current live fire shooting, only knows the hitting situation, but don't know the reasons for hitting or not, and effective improvement measures cannot be formulated.

Combined with Kinect action recognition, the score can be determined. It is suggested to design abundant three-dimensional movements and combine with action recognition of Kinect device. First, identify and bind bone joint points through Kinect's own tools. Then, develop with Unity3D engine. It can be used for static motion recognition and dynamic motion recognition. Based on static motion, it can judge whether the soldier's holding gun posture is accurate under different conditions, determine the score, and judge the soldier's learning progress.

3) Equipment learning

a) Disassembly and assembly of weapons: China has strict arms control, and ammunition is expensive and limited. Soldiers have few real opportunities to shoot live ammunition. It is difficult to master the corresponding skills, and ordinary people are even more difficult to access guns and ammunition.

In traditional military training, weapons are equipped very strictly, and it is not easy to use real weapons for training. There are many limitations even if they are used. It is also necessary to maintain and update all kinds of equipment regularly. The latest modeling technology is used to build a virtual weapon library to experience and learn with VR equipment. In the process of modeling, the high degree of freedom of components can be customized. Weapons can be divided into parts, parts can be enlarged and shrunk for assembly and other operations. At the same time, online interpretation teaching can not only reduce the loss of equipment, but also enable more people to devote themselves to the study of disassembly and assembly of weapons.

Such settings can not only be put into military training after testing the performance of various data, but also into the entertainment industry to enable more military fans to get close contact.

b) Weapon research and development: Virtual shooting range can simulate the future high-tech battlefield environment, the tactical technical performance and tactical use of weapons and equipment, and it will contribute a lot to improving the effectiveness of weapon and equipment system.

From the virtual experiment, it is possible to carry out some tests which are inconvenient for many times in real life, and collect enough reference data. The virtual experiment is also convenient for testing and modifying the performance of the new system/equipment many times, thus avoiding the waste of funds caused by the mistakes in the actual development and production of weapons and equipment, thus shortening the development cycle and improving equipment performance and R&D efficiency.

Adjust the fine parameters of weapon components in virtual system, such as gun caliber, length, weight, initial velocity, acceleration and range. It is not only possible to calculate the trajectory of weapon and get the effect of hitting the target, but also reduce the waste of resources by improper operation and the dangers caused by some errors in real test through the use of virtual operation. Thus, design equipment with better performance in a quick way.

4) Enemy AI module: Some of the training enemies in the system will first combine with artificial intelligence technology, including the role-setting function of automatic routing, group behavior and other simulation, creating a more real enemy state.

Secondly, it will provide the function of setting enemy parameters, such as height, weight, endurance, ordinary moving speed, pursuit moving speed, upper limb/lower limb strength, shooting frequency, etc. The difficulty of training can be changed by adjusting parameters.

5) Record analysis module

a) Record analysis: The system records the trainee's shooting operation process by computer, uploads and integrates the local record files by wireless network, plays back the design process, analyses the results, evaluates the operation level, synthesizes multiple data analysis, and finds out the reasons of success and failure.

b) Data recording in shooting: According to the firing state from the beginning, including the preparation of aiming at the target, the system begins to record data. The data to be recorded includes the current events and the corresponding state of the event. The state includes the location, size, moving speed of the target, direction of occurrence, gun selection and so on. Events include aiming, launching, hitting and so on.

c) File transfer and storage: Records are stored on the local hard disk in the form of video and stored in the database for sorting. When the training is finished, users can search the trainee's name, number, shooting time, test site and so on to retrieve the experimental results.

d) Analysis: Play back the various operations of the trainees, aiming and shooting process, and dynamic analysis of the target and aiming line to formulate the next stage of training plan.

V. Key Technologies in the Construction of Virtual Range

A. Unity3D

Unity3D is a very popular development platform at present. It has powerful function integration ability, supports multi-platform publishing, occupies a large number of domestic developers, and is widely used in the development of various applications and can release various versions to the corresponding application platform.

B. Modeling Technology

Intelligent 3D digital design and 3D intelligent digital scanning technology can only be combined, mainly using Maya and 3D MAX software and 3D scanning technology to build the required model, including equipment, obstacles, scenes and so on. The three-dimensional scanning technology has advantages of getting very small errors, more close to the real object, so that the visual effect is more real, and through the modeling software can get a higher degree of freedom. However, in experimental reality, it has not been developed.

C. Virtual Reality Technology

Virtual reality technology is a new technology that integrates vision, hearing, tactile and olfaction by using computer technology. In a virtual environment of three-dimensional simulation, users can see the virtual natural scene through a special device, and interact with the virtual environment with sensor devices in a certain range, thus get same experience like seeing, hearing, touching and smelling in the real world. This system will mainly use Steam VR and vive development kit for development.

VR technology can create a sensory environment that is infinitely close to reality. It can simulate different mission scenarios in a short time, such as shrapnel-flying battlefield, complex parachuting training, and detailed operation process, so that trainees can understand and grasp the process that should be followed in reality and what kind of combat technology that should be adopted to prepare for real war. Therefore, this technology has great application value in the military field.

D. Human-computer Interaction Technology

Human-computer interaction technology is a technology that realizes human-computer dialogue in an effective way through computer input and output devices. It has four stages of development: basic interaction, graphical interaction, voice interaction and somatosensory interaction. It has a wide range of applications and is closely related to life. It can achieve better experience effect by using human-computer interaction technology.

VI. Necessity of VR Application in Military Field

A. It Can Save Expenses, Reduce Wastage and Increase Safety

Although military VR system needs expensive development cost and equipment, it still saves a lot of money compared with the use of real military equipment, and does not consider the loss of weapons and ammunition. Compared with conventional training methods, virtual training mode has a high security besides great authenticity.

B. It Can Enhance the Training Frequency and Efficiency of Soldiers and Improve Combat Capability

Although VR training system cannot completely replace the practical training, it can carry out more comprehensive and repeated training under the unlimited premise, especially in the narrow space and non-terrestrial environment. VR can show soldiers infinite virtual scenes. In the case of limited space and equipment, multiple soldiers can wear VR equipment for the same training without interfering with each other, and can quickly adjust the training standards and times of different subjects by modifying the parameters of the system.

C. It Can Improve the Psychological Quality of Military Personnel and Help Soldiers to Adapt to Various War Environments

Virtual reality technology and 3D modeling technology can simulate a variety of harsh war environment and various battlefield emergencies, and then exercise and improve the soldiers' response ability and psychological endurance.

D. It Can Assess Weapon Performance and Develop Operational Guidelines

Traditional practical exercises have a long period and high cost. But if VR system is used for training, it will enable more participants to participate in military exercises in a wider scope with less time and less cost. They can also design and carry out many exercises with different schemes, and observe and find out and solve the problems that may exist in actual combat.

It can help instructors to observe soldiers' training carefully.

VII. Conclusion

In recent years, with the in-depth development of VR technology in related fields, it will expand its comprehensive application fields. It has shown important economic benefits and strategic significance in military training and national defense construction. Compared with the past military training and exercises, military simulation technology does not need to be limited to climate, venues and other restrictions, and its cost is far less than the traditional model. It can optimize the efficiency and mode of military learning. With the help of VR simulation technology, trainees can move from classroom to "real" battlefield, from theory to practice, and feel immersed vision. Under targeted training, it gives consideration to safety and improves soldiers'

proficiency more quickly, and strengthens all aspects of comprehensive quality. The application of VR in military field has quite good prospects, and it will be popularized in military field in the future. At the same time, VR technology will continue to expand in other fields.

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