

Research and implementation of virtual reality technology to build a 3D application that simulates the disassembly and assembly of equipment and weapons (DASim)

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ABSTRACT

Disassembly and assembly of equipment and weapons (E&W) is a regular work of great importance in the military. Implementing the right procedures and quickly will help increase efficiency and ensure the safety of the citizens and weapons. However, the training and training of cadres, technical staff, trainees and soldiers to master the skills of disassembling equipment and weapons takes a lot of time and resources, and there are also many risks in the practice process. Virtual reality (VR) application is a time-saving and effective solution for training knowledge and training weapons disassembly skills, not only allowing users to interact with a virtual environment like reality, but also minimizing potential risks in the process of practicing with real equipment and weapons, without mastering the process of disassembly and maintenance.

In this paper, the research team will present the approach, build an algorithm and design a software program to simulate the disassembly of weapons equipment using 3D virtual reality technology. The software consists of three main modules: theory, practice, testing, helping officials, technical staff, trainees, and soldiers master knowledge from theory to practice process, forming skills before operating directly on real weapons. The study concretizes through the example of establishing the content of the structure, disassembly process and practice of disassembling AK submachine guns, 7.62 mm PKMS. In addition, the paper will also evaluate the effectiveness of the use of VR in training and training personnel to disassemble and assemble weapons.

Keywords: Disassembly of equipment and weapons; Virtual reality; Simulation technology; VR.

1. INTRODUCTION

The rapid evolution of technology is increasingly reshaping how we approach and perform complex tasks. The application of Virtual Reality (VR) technology is opening up promising possibilities in the fields of engineering in general and national defense and security in particular, including the disassembly of weapons equipment. The simulation of weapons on the computer and the practice of disassembly skills using VR technology help learners experience in a realistic, vivid, realistic 3D virtual environment to improve efficiency and ensure safety in the learning process [1-3]. In the world of virtual reality, technology has been widely applied to support technical and tactical training in the military. Software to simulate the features, structure, principle of operation and disassembly of weapons such as Weapon assembly training [4], World of Guns: Gun Disassembly [5]; Virtual Simulation Complex software to simulate weapons equipped with intensive training of Ukrainian artillery cadets [6],... has shown high effectiveness in

training skills for cadres, technical staff, trainees and soldiers. However, the software in the world has its own characteristics and is not suitable for the weapons in the service of our Army. In the country, in recent years, simulation products have also been researched and applied to teaching and learning, initially showing the positivity of a new approach. Simbook software simulates the features, structure and principle of operation of some types of infantry weapons; Virtual shooting school for training shooting techniques of the Institute of Simulation Technology, Military Technical Academy is applied at military academies and schools to help cadets, soldiers research and train weapons in an intuitive, lively, easy to remember and understand the nature of the problem.

In order to continue to apply more deeply and widely in training and training activities in the army, we research and develop 3D software to simulate the disassembly of equipment and weapons using VR technology, gradually complete and equip schools, units, and support cadres, staff and cadets to master the implementation process, perfect their skills before practicing with real equipment and weapons, ensure the safety of people and materials, and save security and defense resources.

2. SOFTWARE DEVELOPMENT

2.1. Technology Platforms

3D software simulates disassembly and assembly E&W using leading-edge tools and technology platforms such as 3DSMAX, Unity3D and Oculus Integration,... First, 3D modeling data and animation data are designed on the 3DSMAX software. The software is equipped with and integrates 3D image processing tools with built-in effects with many advanced features, making the image true, sharp, and smooth animation. Later, 3D models and animations will be uploaded to Unity Editor to continue the process of building simulation scenarios, display functions and dismounting in the virtual environment. Finally, the software is connected to the Oculus Quest virtual reality headset through Oculus Integration technology.

Oculus Quest can directly support head tracking and hand tracking process with the sensors and cameras on the headset. The headset detects the position, hand orientation, and configuration of the fingers. Once detected, the computer vision algorithm tracks hand movement, direction, and uses this information as input to determine what action to take. Compared to using gloves or controllers for interaction, tracking hand movements with the camera on the Oculus headset has several advantages: it is natural and convenient, giving users freedom to interact thanks to the tracking of hand gestures and positions, enhancing the mobile experience. However, the disadvantage of this method is that the detailed interoperability and accuracy are lower than with the use of controllers or gloves. However, to accurately manipulate and follow the rules when disassembling equipment and weapons, the hand tracking feature on Oculus Quest glasses with the camera on the headset is more suitable.

The mathematical principles and equations related to Virtual Reality (VR) are used in the software, such as Stereoscopic 3D Rendering, Field of View, Head Tracking and Orientation, Coordinate Transformations, and Optical Flow for Hand Tracking. Stereoscopic 3D Rendering is used to create the illusion of depth perception in VR which involves rendering separate images for the left and right eyes. The camera projection

matrix, which is calculated for each eye, is presented in the following equation:

$$P = M * V * R * T \tag{1}$$

where P is the projection matrix, M is the model matrix, V is the view matrix, R is the rotation matrix, and T is the translation matrix.

Orientation tracking is essential for tracking the user’s head movements in VR. The orientation data is represented and updated by quaternion mathematics, and the equation for quaternion multiplication is a fundamental part of the head tracking:

$$q = q_1 * q_2 \tag{2}$$

where q is the resulting quaternion, $q_1 * q_2$ are the input quaternions.

Transforming objects in 3D space is a key concept in VR environment in which homogeneous transformation matrices are used for translating, rotating, and scaling objects in 3D space. The multiplication of these matrices is a fundamental operation:

$$P_{new} = T * R * S * P_{original} \tag{3}$$

where P_{new} is the transformed position, T is the translation matrix, R is the rotation matrix, S is the scaling matrix, and $P_{original}$ is the original matrix.

2.2. System Design

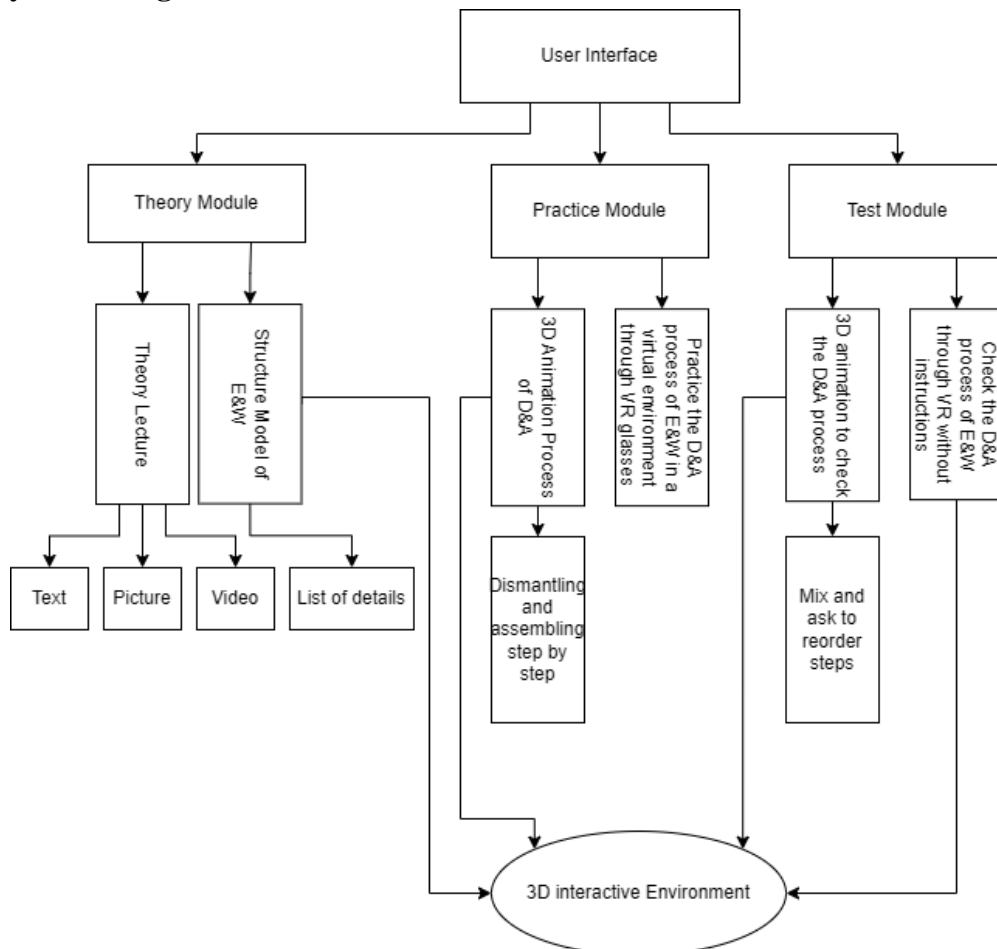


Figure 1. Functional model of DASim software system.

The 3D software simulates the disassembly and assembly of equipment and weapons developed for teaching and learning towards three main objectives: supporting teachers to teach theoretical lessons on the uses, structure, operating principles and disassembly processes of the types of equipment and weapons; supporting students to check their knowledge, master the process of disassembly, fitting and practicing the skills of disassembly and fitting with types of equipment and weapons through virtual reality environment.

From the above requirement, the software is designed into three main modules: theory, test, practice.

The theoretical module includes theoretical lectures and 3D models, animation of E&W, teaching and learning about the uses, structure, operating principles, and procedures for disassembling and assembling weapons through videos, images, texts, 3D models for students to understand and master weapons.

The inspection module includes a 3D animation to check the process of disassembly (or assembly) of equipment and weapons (automatic disassembly, assembly) and check the process of disassembly and assembly of E&W VR without instructions. This module allows the user to select the order of actions under the dismounting process, for the purpose of checking the proficiency of the dismounting and mounting process of the trainee, as a basis for practicing dismounting and mounting.

The practical module allows students to practice the process of disassembling and assembling weapons in a virtual environment through VR glasses.

The system function model is shown in detail in figure 1.

2.3. Implementation Arrangement

The process of building software consists of three stages: collecting documents, images, videos; building 3D scenarios and data; building software (figure 2).

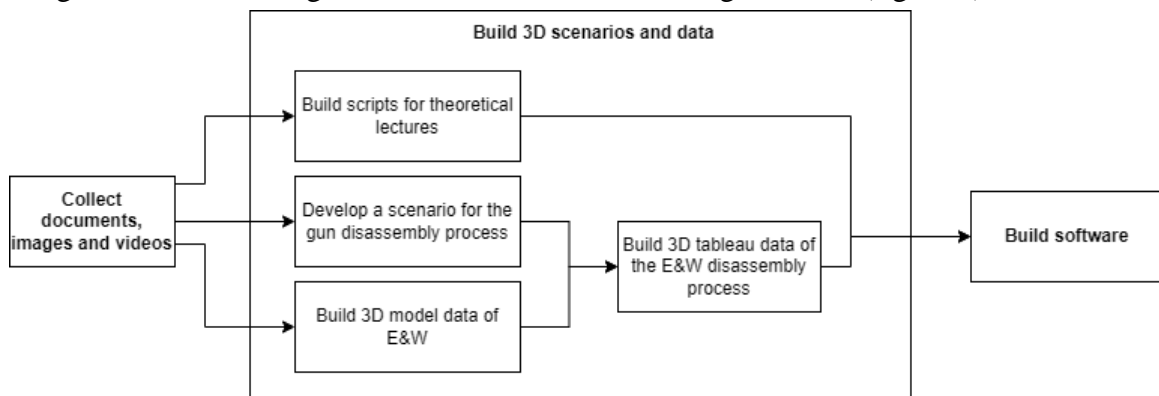


Figure 2. Software building process.

Firstly, collect data from the syllabus and lecture arsenal "Typical equipment of general weapons" of the Department of Weapons, Department of Mechanical Engineering, Military Technical Academy. This data includes documents, images, videos of uses, structures, operating principles and procedures for removing and installing E&W. Within the scope of this paper, the authors go into collecting and building data for AK submachine guns and 7.62 mm PKMS machine guns. These are two types of guns

that are regularly trained and used in the Army. From the actual requirements of teaching the disassembly of the above guns for students in Military schools, the following procedures were selected by the authors to develop a simulation scenario: the normal disassembly and installation process of AK submachine guns; the normal disassembly and installation process of the 7.62mm PKMS machine gun; the complete disassembly and installation process of the 7.62mm PKMS machine gun.

Next, building 3D model data and scenarios of theoretical lectures, scenarios of E&W disassembly process. Then, build up 3D animation data to disassemble the gun. When building 3D animation data, it is necessary to model the dismantling and mounting procedures. The disassembly process of a weapon can be done from the large parts down to its subparts, and then on to the next large part, sequentially, as shown in figure 3.

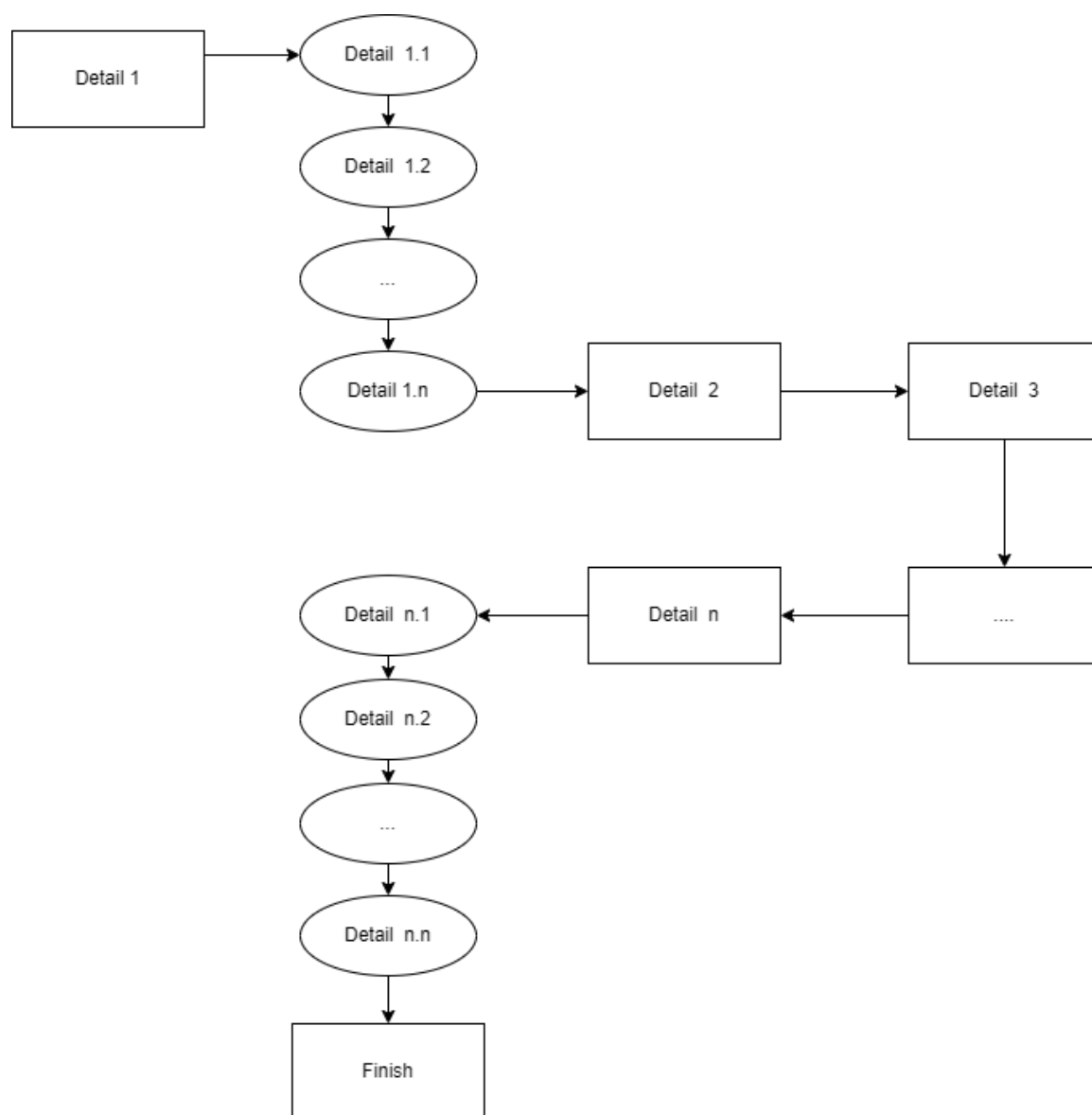


Figure 3. Modeling the process of disassembling and assembling weapons.

Finally, proceeded to build software including database design, user interface design, layer design and Oculus glass integration. The software execution modules include are shown in figure 4.

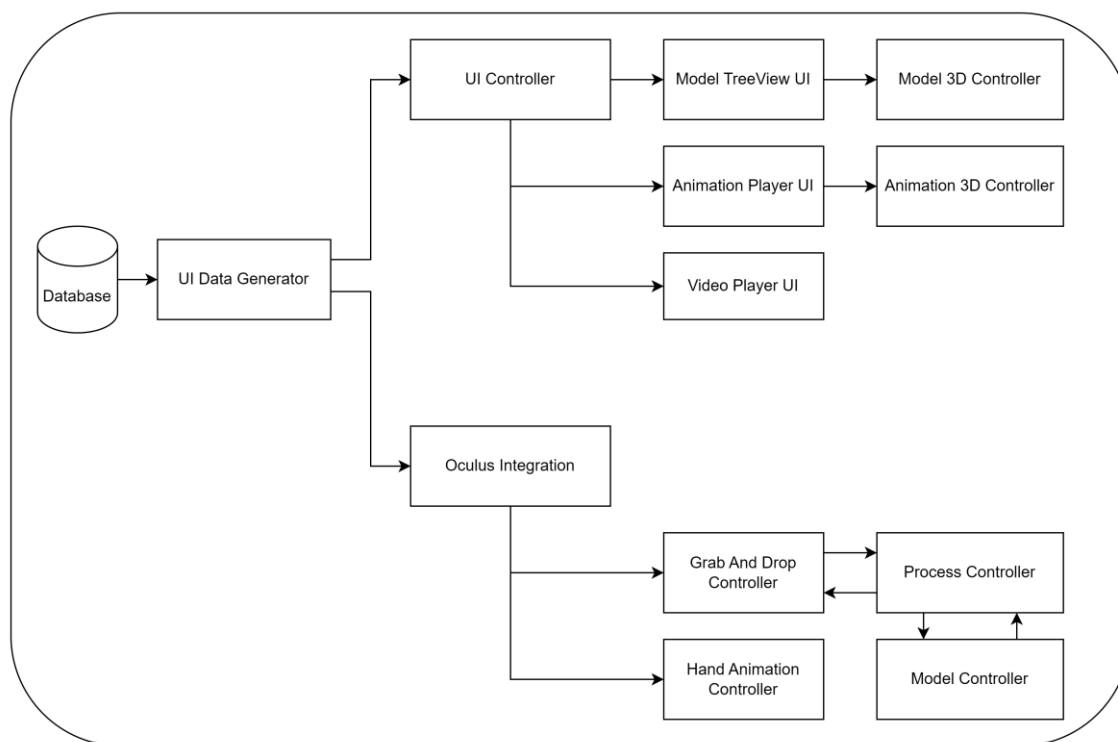


Figure 4. Execution module of infantry weapon training software.

1) Database: database that stores lecture attribute data (text, images, videos), 3D model data, animation data

2) UI Data Generator, UI Controller: 2D user interface

3) 2D Video Player: 2D video slideshow

4) Model TreeView UI: displays weapon composition, shows details, detailed clusters in a 3D environment, including layers:

- OrbitCamera: interactive moving, zooming, rotating 3D object

- TreeViewController: generate and initialize 3D model, display a detailed list of parts on a 2D interface, select and display toggle with each detail and cluster of details, change the transparency to clarify the selected details

5) Animation Player UI: 3D animation scenario

6) Animation 3D Controller, Model 3D Controller: controlling the camera in a 3D environment

7) Oculus Integration: is an Oculus SDK to support communication between Oculus' glasses and controls with Unity, the module consists of the following layers:

- GrabbableController: contains a list of weapon details and clusters, controls hold and drop events on VR with weapon and each detail, clusters of weapon details, controls the status of objects during hold and drop.

- ProcessController: contains the disassembly process sequence list information of the weapon, controls the events and allows holding and dropping based on the current step of the process, updates each process according to the events of GrabbableController.
- HandAnimationController: performs hand movement according to the Controller or Hand Tracking of Oculus, controls the shape of the hand according to the detail or cluster of details in hand.
- Model Controller: generating, assigning, initializing models, controlling movement, grasping details

In which, the functional model of the component modules is shown in figure 5.

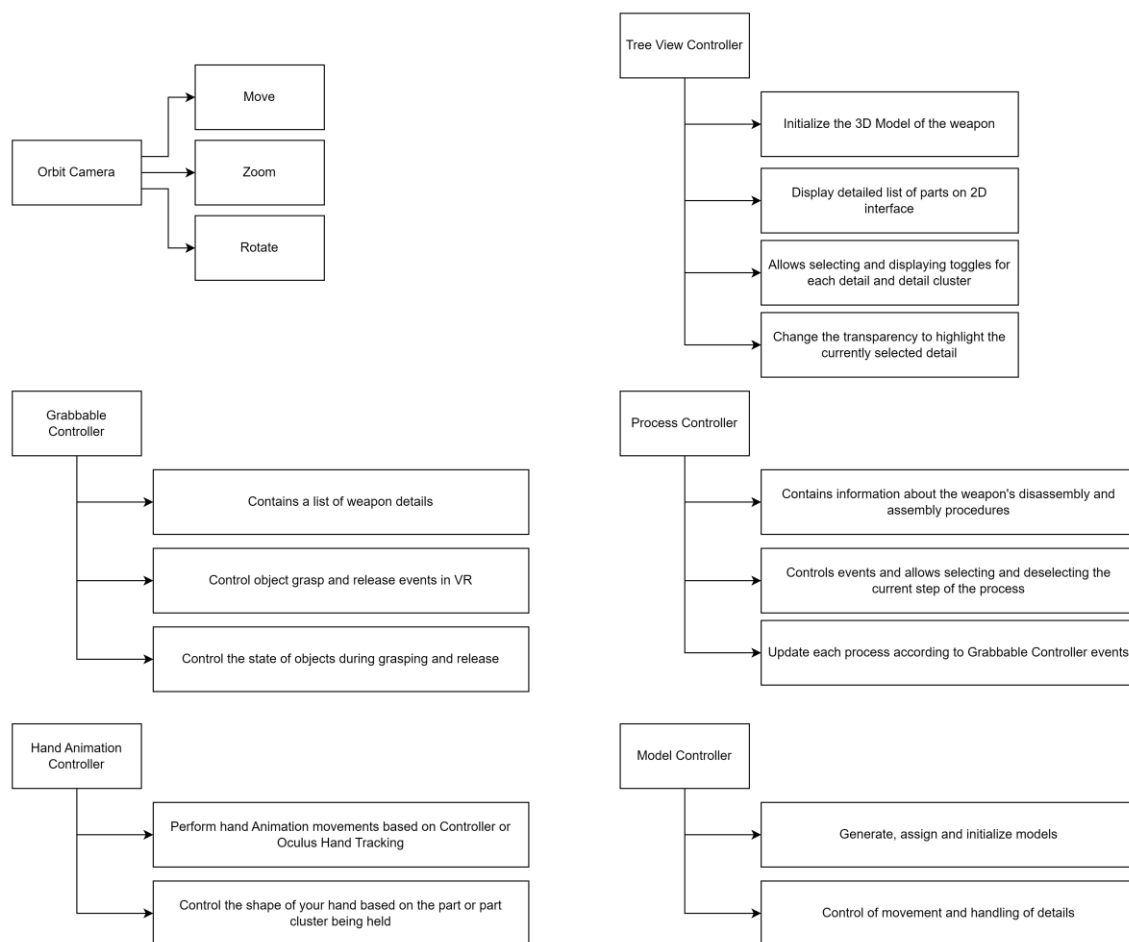


Figure 5. The functional model of the component modules.

3. ILLUSTRATION RESULTS

Infantry weapon training software is organized in the form of a library that includes a variety of weapons, which are teaching tools for teachers and learning for students. The software includes the following items: theory, test, practice.

3.1. Theoretical modules

In this section, teachers can show and teach about the features, structure, operating principles, disassembly theory, assembly theory of guns.

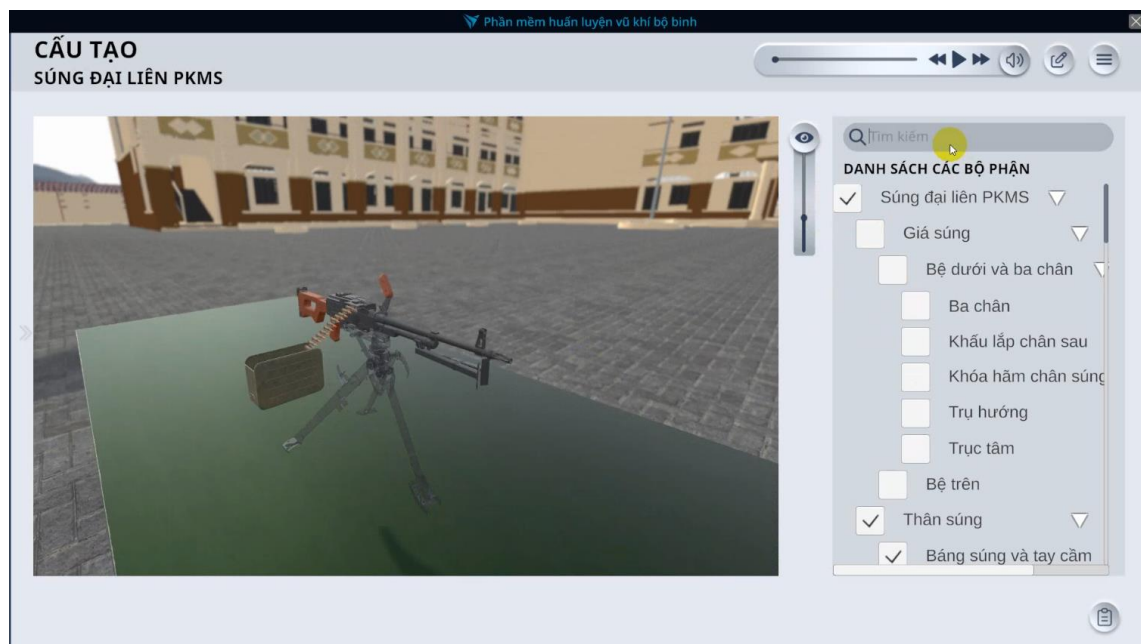


Figure 6. Interface for teaching the structure of PKMS machine gun.

3.2. Test module

The parts are mixed in order so that they match which step in the disassembly process, assembled sequentially from step one. If selected correctly, the screen shows the scene in which the step was performed. If they make the wrong choice, they do it again.

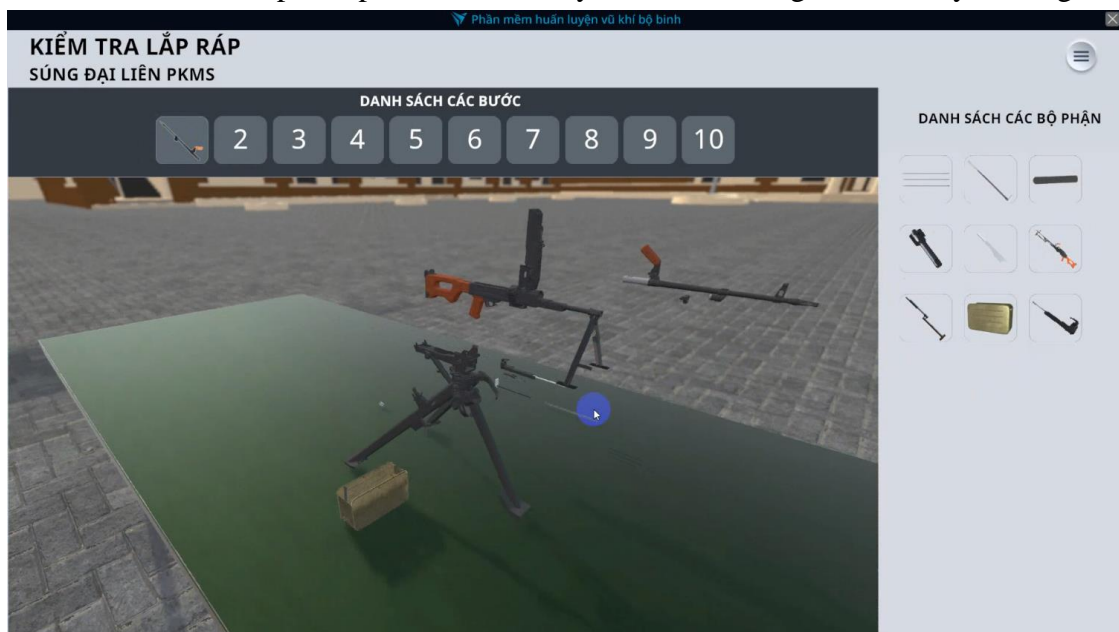


Figure 7. Interface for testing the assembly of PKMS machine gun.

3.3. Practical module

Students can practice disassembling the gun in a 3D animation or virtual reality environment using Oculus Quest 2 glasses.



Figure 8. Interface to practise the animation assembly of PKMS machine gun.



Figure 9. VR practice interface for dismounting of PKMS machine gun.

4. CONCLUSIONS

With the integration of the theory of uses, features, structure, operating principles and practice of weapon disassembly, DASim software is a powerful support tool for the teaching and learning of teachers and students in Military schools. The application of virtual reality technology helps students practice disassembling real and vivid virtual

environment weapons. Thereby improving the learning efficiency and the ability to master weapons and equipment of students. The software can be further developed for complex equipment and weapons as well as for vocational education for other professions inside and outside the military.

REFERENCES

- [1]. L. Wei. "Development of Virtual disassembly and assembly platform for marine air compressor". Journal of Physics: Conference Series, vol.1884, pp. 012011, (2021).
- [2]. J. Zhang. "Design of VR Engine Assembly Teaching System". Journal of latex class, (2022)
- [3]. M.H. Abidi, A. Al-Ahmari, A. Ahmad, W. Ameen, H. Alkhalefah. "Assessment of virtual reality-based manufacturing assembly training system". The International Journal of Advanced Manufacturing Technology, (2019).
- [4]. Lepopoly. *Weapon Assembly Training*. <https://leopoly.com/2023/06/30/weapon-assembly-training/>, (2014).
- [5]. Steam. *World of Guns: Gun Disassembly*. https://store.steampowered.com/app/262410/World_of_Guns_Gun_Disassembly/, (2014).
- [6]. V. Savchenko, A. Derevjanchuk, T. Dzyuba, D. Moskalenko. "Intensive Training Model for Artillery Cadets Using 3D Simulators". Advances in Military Technology, vol. 18, pp. 22-48, (2023).
- [7]. *Meta Getting started with Hand Tracking on Meta Quest headsets*. <https://www.meta.com/help/quest/articles/headsets-and-accessories/controllers-and-hand-tracking/hand-tracking/>, (2023).

TÓM TẮT

Nghiên cứu, ứng dụng công nghệ thực tại ảo xây dựng phần mềm 3D mô phỏng tháo lắp trang thiết bị, vũ khí (DASim)

Tháo lắp trang thiết bị, vũ khí (TTB-VK) là một công việc thường xuyên có ý nghĩa hết sức quan trọng trong quân đội. Việc thực hiện đúng quy trình và nhanh chóng sẽ giúp tăng hiệu quả và đảm bảo an toàn cho người và vũ khí. Tuy nhiên, việc đào tạo và rèn luyện cán bộ, nhân viên kỹ thuật, học viên, chiến sĩ nắm vững kỹ năng tháo lắp trang thiết bị, vũ khí mất nhiều thời gian và tài nguyên, đồng thời cũng gặp nhiều rủi ro trong quá trình thực hành. Ứng dụng thực tại ảo (VR) là một giải pháp tiết kiệm thời gian và tăng hiệu quả cho việc đào tạo kiến thức và rèn luyện kỹ năng tháo lắp vũ khí, không chỉ cho phép người dùng tương tác với một môi trường ảo giống như thực tế, mà còn giảm thiểu những rủi ro tiềm ẩn trong quá trình thực hành với trang bị, vũ khí thật, khi chưa nắm vững, thành thực quy trình tháo lắp, bảo dưỡng.

Trong bài báo này, nhóm nghiên cứu sẽ trình bày phương pháp tiếp cận, xây dựng thuật toán và thiết kế chương trình phần mềm mô phỏng tháo lắp trang thiết bị vũ khí ứng dụng công nghệ thực tại ảo 3D. Phần mềm gồm ba mô-đun chính: lý thuyết, thực hành, kiểm tra, giúp cán bộ, nhân viên kỹ thuật, học viên, chiến sĩ nắm chắc kiến thức từ lý thuyết đến quy trình thực hành, hình thành kỹ năng trước lúc thao tác trực tiếp trên vũ khí thật. Nghiên cứu cụ thể hoá qua ví dụ thiết lập nội dung về cấu tạo, quy trình tháo lắp và thực hành tháo lắp súng súng tiểu liên AK, đại liên PKMS 7.62 mm. Ngoài ra, bài báo cũng sẽ đánh giá hiệu quả của việc sử dụng VR trong việc đào tạo và rèn luyện nhân viên tháo lắp vũ khí.

Từ khoá: Tháo lắp trang thiết bị; Vũ khí; Thực tại ảo; Công nghệ mô phỏng; VR.