Journal of Physics: Conference Series

PAPER • OPEN ACCESS

A Command and Control System for Air Defense Forces with Augmented Reality and Multimodal Interaction

To cite this article: Long Chen *et al* 2020 *J. Phys.: Conf. Ser.* **1627** 012002

A Command and Control System for Air Defense Forces with Augmented Reality and Multimodal Interaction

Long Chen[*], Wei Wang, Jue Qu, Songgui Lei and Taojin Li

Air force engineering university in Xi 'an, shaanxi province, China

[*]E-mail:2940782854@qq.com

Abstract. This work proposes a framework for the command and control system of air defense forces based on augmented reality technology. The system uses Microsoft HoloLens hardware as a carrier to realize the holographic display of battlefield situation information. The system can help the commander to perceive and control the situation on the battlefield in an efficient manner, in order to reduce the decision-making time of the commander. Commanders can efficiently interact with the system through gestures and voice, deploy simulated military units in the system through gestures, and send commands to weapon systems through the system. At the same time, the system also supports multi-person real-time collaborative operation, which enables the joint decision-making and sharing of commanders. This system is of great significance to improve operational efficiency and reliability, and at the same time provides an open platform for operational process planning, deduction, simulation, and verification evaluation.

1. Introduction

In the field of military science , "command and control" (C2) the term originated in the "Art of War" (1836) a book, Jomini used "Conmmand" and "Control of Operations" respectively when he expounded "army command and operational Control" [1]. Command and control system refers to the information system for commanders and their command organs to conduct command and control of combatants and main battle weapons and equipment. It is mainly composed of hardware platforms such as information processing, display, transmission and monitoring, as well as processing of system command and combat functions. Software composition . The accusation system has the functions of intelligence receiving and processing and situation generation, auxiliary decision-making, combat simulation and evaluation, information display and distribution, tactical calculation, command issuance, security and confidentiality, force management, training simulation, etc. Its basic task is to assist commanders to master the battlefield in time Situation, scientifically formulate operational plans, and quickly and accurately issue operational commands to the troops.

Sources many modern battlefield, the war situation the rapidly changing, the explosive growth of information to the commander 's perception of the battlefield situation has brought new challenges. The battlefield information needs to be quickly transmitted to the commander through the information display interface. After the commander makes a decision, the control information is quickly fed back to the accusation system through appropriate means. The traditional way of displaying system information is mainly based on the two-dimensional computer screen. The information display is not intuitive and efficient, which leads to the increase of the commander's cognitive load and the low efficiency of human-computer interaction. Augmented reality, as a tool that assists people in cognition and interaction in the real environment, has its own technical characteristics to provide new solutions to the situational awareness of commanders. Augmented reality systems used in military command and control systems in can greatly improve warfighter situational perception can force [2]. This article uses VR and MR technology to develop a set of air defense anti-missile holographic battlefield command and control system. The system provides a holographic battlefield situation information construction and command interaction implementation method, which can enhance the realism and immersion of situation awareness, enhance the system's intelligent information service level, and intelligently and efficiently provide images for commanders and staff. The intuitive battlefield situation and visual information interaction interface realize a kind of intelligent information service method for future advanced command post that supports different combat personnel and different combat forms.

2. Background

2.1. Status Quo of AR Application in the Army

AR technology is also being applied in the military as well. In order to improve the effectiveness of command and control cabin human-computer interaction, a number of US military research institutions to carry out research next-generation allegations cabin human-computer interaction, the US Defense Advanced Research Projects Agency from 2008-2014 continued support aimed at improving Research on the augmented reality combat command human-computer interaction system ARC4 (Augmented Reality Command, Control, Communicate, Coordinate) of tactical units in outdoor day and night sports combat [3]. United States space agency in Space Situation Awareness (SSA)User Defined Operating Picture (UDOP)) project to explore augmented reality environment in 2D , 3D information display problems, analyzed and in physical space AR objects perform multi-modal human-computer interaction problems based on eye movements, gestures, speech, and controllers, problems with scaling, positioning, and directional operations of AR objects . 2D vision, 2D texture, and 3D visual object visualization in AR virtual environment Methods, such as unconstrained AR virtual space that can configure the user's virtual environment [4].

2.2 Introduction to Holoens

HoloLens is a typical hardware device of mixed reality technology. When users wear the device, their vision is not blocked, and they can still walk in real space freely [5]-[7], this is shown in figure 1. HoloLens can track the user's movement and line of sight changes, project the virtual holographic image into the user's eyes in the form of light projection, and at the same time support the user to complete various forms of real-time interaction with virtual objects such as gestures, voices and gazes. HoloLens has the following advantages over VR glasses.

Figure 1. HoloLens holographic processing unit

(1) Small size, can work independently, do not need additional host to provide computing power. Traditional VR glasses need to render the entire virtual environment frame by frame, while AR only

needs to render a small number of objects superimposed in the real space, which greatly reduces the computation.

(2) Scene positioning. The bottom layer of HoloLens comes with its own environment mapping and positioning algorithm, which can adapt to various environments without additional auxiliary pendants. The hologram in HoloLens does not change its position in real space when the user is temporarily away, because this environmental information is already stored in the HoloLens.

(3) There are many ways to interact. In the virtual scene, users can operate on virtual objects in a variety of ways, which are voice, gesture and gaze respectively. The operation of virtual objects by gesture interaction has replaced the existence of the mouse in traditional computers.

(4) General application. The operating system of the HoloLens platform is Windows Holograpic, which is also customized based on Windows 10. So the Windows 10 UWP universal application can run smoothly on HoloLens. This not only reduces research and development and migration costs, but also enables development efficiency to be greatly improved.

3 Technical Approach

The system architecture is shown in Figure 2. The system can support multiple users simultaneously online for use, the user through gestures, voice and system be multi-channel interaction. The system consists of a database, a Server / Client server, and a Host domain. The database is used for the storage of data required for system operation and the construction of system virtual simulation scenarios, including combat scenario data, combat weapon 3D model libraries, 3D terrain libraries, and various model control scripts. Server / Client server is used to realize the real-time interaction of multiple Hololens , and provides conditions for communication between Hololens . The Host domain contains system interaction equipment Hololens and users. The system is constructed using the following technology.

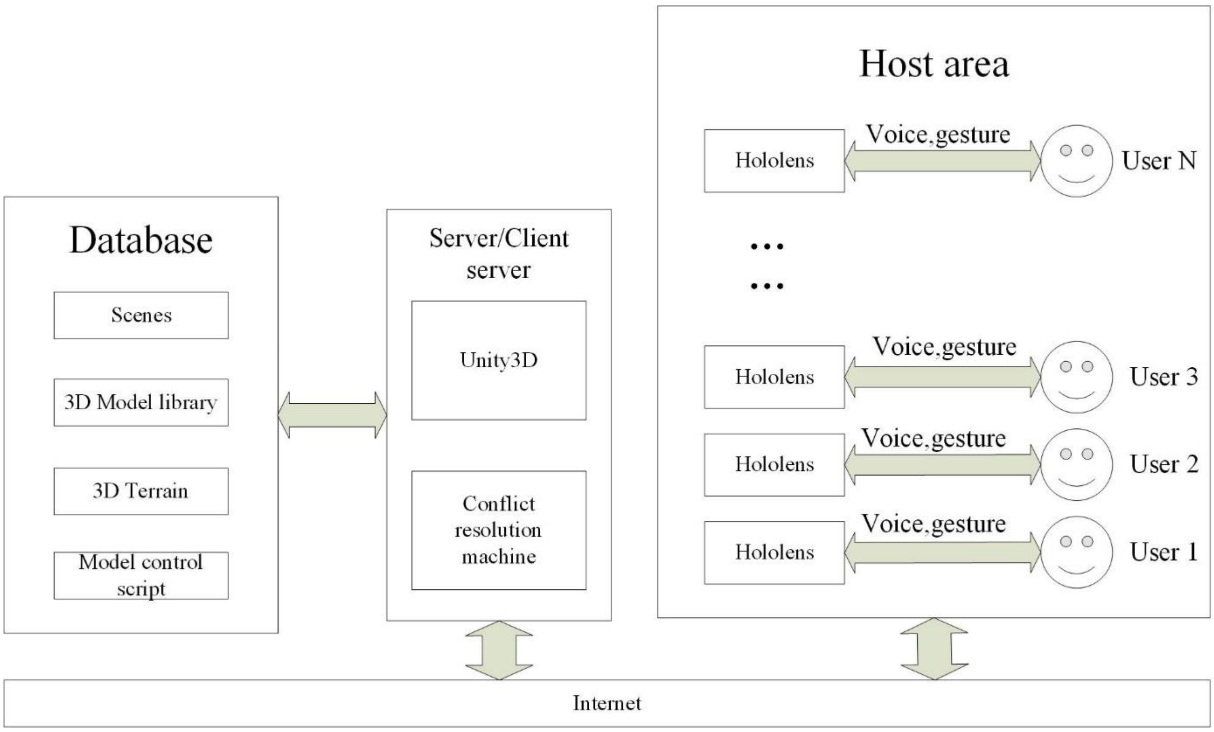


Figure 2. System architecture diagram

3.1 Interface design technology

The interface interaction in mixed reality is different from the traditional two-dimensional graphical interaction in the form of windows, icons, menus, and cursors (WIMP) . Its purpose is to overcome the two-dimensional limitations of traditional interaction and construct a more Natural and intuitive three-dimensional interactive environment. Interactive devices currently used for desktop graphical interfaces, such as a mouse, trackball, and touch screen, have only two degrees of freedom (translation along the plane x and y axis) , while objects in three-dimensional space have the characteristics of moving in six directions of freedom, including along the three-dimensional space X , Y , Z axis translation and about the X , Y , Z axis rotation, due to the increased degree of freedom, windows, menus, icons and conventional two-dimensional cursor in the three-dimensional interactive environment will destroy the sense of space, and also Makes the interaction process very unnatural, so new interaction interfaces need to be designed. Three-dimensional user interface surface does not replace the traditional two-dimensional graphical user interface paradigm, but to solve the poor performance of traditional interactive mode field, compared to traditional two-dimensional graphical user interface, three-dimensional user interface has the following advantages:

(1) Enhance the user's comprehensive ability to process information, these abilities include cognition, perception, learning and memory;

(2) Provide a new space for organizing, carrying, and presenting more complex information, which can more clearly and intuitively show the relationship and difference between different types of information;

(3) Make the information display more direct and easier to understand; it can introduce many more natural and rich behaviors in human reality into the traditional human-computer interaction.

The user interface in the mixed reality system includes two parts: 3D Widget and 3D model. 3D Widget is a concept derived from a two-dimensional graphical interface, and is an entity that encapsulates three-dimensional geometric shapes and their behavior. The three-dimensional geometric shape refers to the appearance of the 3D Widget itself, which is generally a rectangular three-dimensional patch that can be scaled, rotated, and stretched in a three-dimensional space. The behavior includes the interactive control of 3D Widget with other objects in the 3D scene and the display of object information. 3D the Widget interact also comprise two types, one 3D the Widget itself as the 3D objects in the scene, can be changed by its interaction position, size, direction, and other attributes; Second 3D the Widget contents displayed, by gestures, gaze Etc. for interactive operations. The specific design is:

(1) Position of the 3D Widget under the viewpoint: As an object in the virtual scene, the 3D Widget can be moved, rotated, and scaled by the user. This operation can be controlled by gesture signals. In the mobile Widget mode, the incremental matrix is moved by the hand. To calculate the amount of movement of the 3D Widget , the specific calculation formula is:

$$M_V = M_H M_{H'}^{-1} \cdot M_{V'} \tag{1}$$

M_V is the matrix of the current frame 3D Widget under the viewpoint, M_H is the current frame virtual hand gesture obtained from gesture recognition, $M_{H'}^{-1}$ is the virtual hand gesture obtained from the previous frame gesture recognition, and $M_{V'}$ is the matrix of the previous frame 3D Widget under viewpoint .

(2) 3D Widget 's movement with the head: After the user's head moves, the 3D Widget remains stationary relative to the objects in the real world. Therefore, after obtaining the posture of the head movement, calculate the 3D Widget from the head The offset matrix obtained by motion:

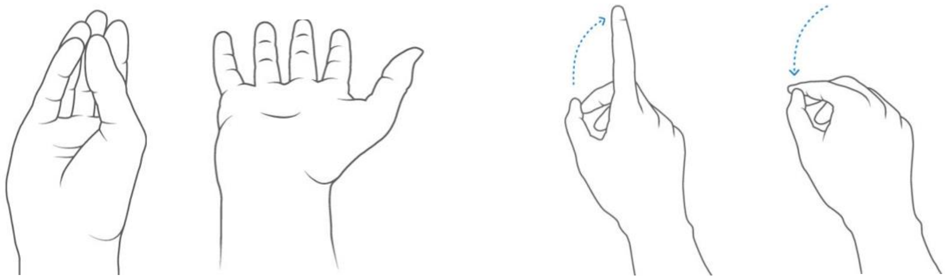
$$M_W = M_h M_{h_0}^{-1} \cdot M_{W_0} \tag{2}$$

M_W current frame 3D Widget's position matrix relative to the head, M_H is the current frame head pose matrix, M_{H0}^{-1} is the initial pose of the head, and M_{W0} is the 3D Widget's position matrix in the initial state.

3D Widget activation status determination: the face of the interface of 3D Widget and 3D models, interactive operation for only one of the only active object. The system judges the interference between the ray formed by the center point of the screen as the origin and the direction of the viewpoint and the 3D Widget , and calculates the first object that interferes with the ray. The object is the active 3D Widget .

3.2 Implementation of multi-channel interaction

The realization of interactive gestures is another highlight of the system. After selecting the target, interactive operations are performed through interactive gestures , completely eliminating the dependence on input devices such as the mouse and keyboard. Generally in the research of augmented reality interactive gestures, interactive gestures are classified into static gestures and dynamic gestures for detection and recognition respectively according to the application purpose and gesture state . This system uses a dynamic gesture detection, the hand is placed in front of the user 120 ° × 120 ° viewing angle where , by collecting human hand depth of bone nodes, backbone nodes trajectory obtained as a main characteristic gesture recognition, by comparing the starting backbone nodes, the end point and the moving distance, and calculate the classification process, the final result obtained gesture recognition. Two important gestures are Bloom and Air Tap, as shown in Figure 3 :



(a) Bloom gesture (b) Air Tap gesture

Figure 3. Gesture diagram

By Microsoft provides MRTK (Mixed Reality Tool Kit) the SDK can design different gestures in response , using Gesture the Recognizer function can create different gesture operation type , call the Input Module1 space IManipulationHandler classes and IInputClickHandler class OnManipulationStarted, OnManipulationUpdated, OnManipulationCompleted, OnManipulationCan---celed function to define different gesture trigger events.

In terms of voice interaction, you can enable the dictation recognizer by editing MicrophoneManager, write the Global Listener function to start global dictation, and then call the KeywordRecognize function in the I SpeechHandler class to specify the vocabulary to be recognized. The GrammarRecognize function defines the relevant grammar. After the specified vocabulary is recognized, Use OnPhraseRecognized function to trigger the corresponding event.

3.3 Multi-person collaboration technology

The display and command decision of battlefield situation requires the cooperation of multiple people, so the system should be able to satisfy multiple users to operate a situation scene at the same time, and the results of the operation are simultaneously displayed in all equipment. The two main issues that need to be addressed in multi-person collaboration are :

(1) Decision conflict in multi-person collaboration

(2) Scene consistency in multi-person collaboration.

When performing multi-person collaborative operations on virtual battlefield decisions, multiple operators may operate and control the same virtual object at the same time. If the system cannot handle the situation where multiple objects access the same object, it may cause system abnormalities or decisions The results are confusing, so it is particularly important to design a sound multi-person collaborative access conflict resolution strategy. The server should use the data information of the users participating in the collaborative operation to perform simulation calculations to judge the conflict and effectively resolve the conflict.

In the command and control decision-making process, each user 's operation has the same weight for server simulation calculations. Each calculation must be performed according to the user 's latest frame of complete operation data. The calculation is completed and displayed in real-time visualization. Affect the operating experience of each user. When multiple users work together, users will consciously avoid conflicts and operate in order. The server simulation simulation calculation will complete the calculation within a set period. Generally, there will not be conflicts when different instructions are issued for the same object, but unavoidable access conflicts will also occur. For example, when two users make a decision on a certain mobile in a decision There will be differences in the deployment of forces and simultaneous deployment to different locations. At this time, data conflicts will occur in the calculation. Therefore, it is necessary to use a certain strategy to resolve conflict operations, as shown in Figure 4 . When the server calculates according to the latest frame of complete operation data of each user, if there is a conflict of access data during the process, the server will select the correct client operation according to the specific first-come-first-served rule as the preferred operation. , And then judge the conflict of access data until the conflict disappears, and finally output the calculation result and visualize it.

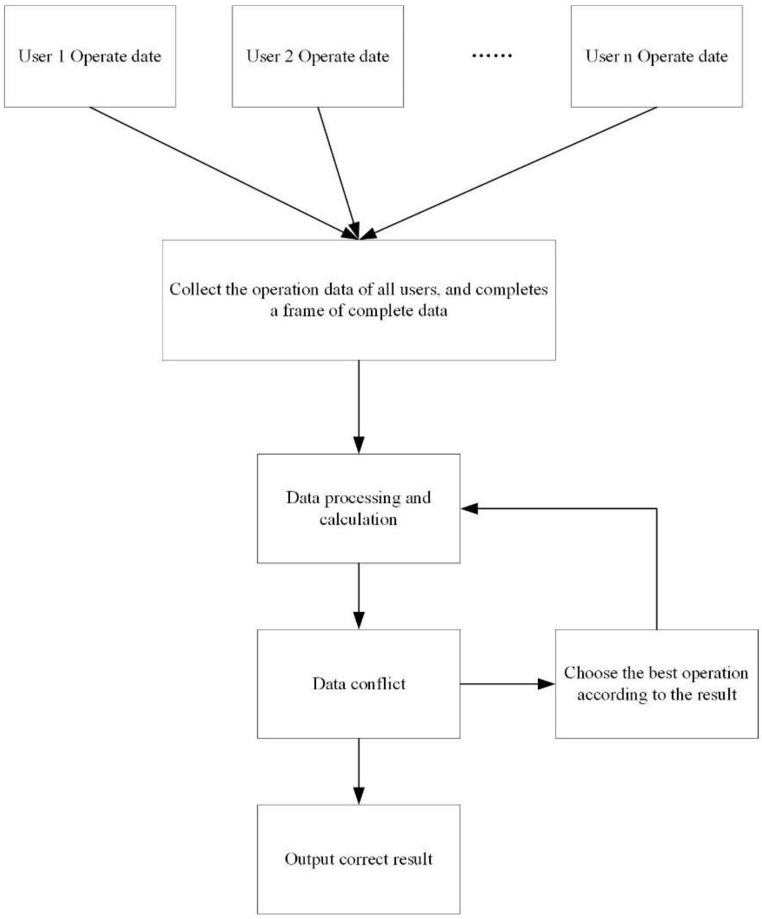


Figure 4. Conflict Resolution Strategy

The multi-person collaboration solution of this system is realized through the collaboration of multiple HoloLens glasses. During the collaborative operation, each user participating in the disassembly operation interacts with the virtual model through gestures, voice, gaze, and only the user sees in his HoloLens glasses The virtual model is the same as the virtual model seen by other users, which is the real collaborative operation. Therefore, the system must ensure the real-time consistency of the position and state of the virtual model in the real scene. For example , when user 1 performs the operation, user 2 can also see the entire operation process, and when the state of the virtual model that user 2 sees is the same as the state that user 1 sees, he can also perform his own operation, and other users participating in collaboration The operation result of user 2 can be seen in real time .

Multi-person collaboration data transfer is achieved through the Socket protocol, through the Server / Client server interface to build the server and transfer client data. This system introduces a message consistency check in the host domain in the server - client one-to-one communication mode, and adds a real-time message synchronization mechanism between devices based on the traditional socket network connection, as shown in Figure 5 . When any shared message data in the host domain marked with the [SyncVar] label is modified on the server and client , the data is shared to all devices in the host domain through the wireless network , and before responding to the received data operation, the device will data received in the host conducted public domain, whether the data information to check all equipment received unanimous, as the same fruit, then further rendered according to the message data, otherwise, have to give up all the equipment in response to this message, until the device is shared message The data becomes consistent.

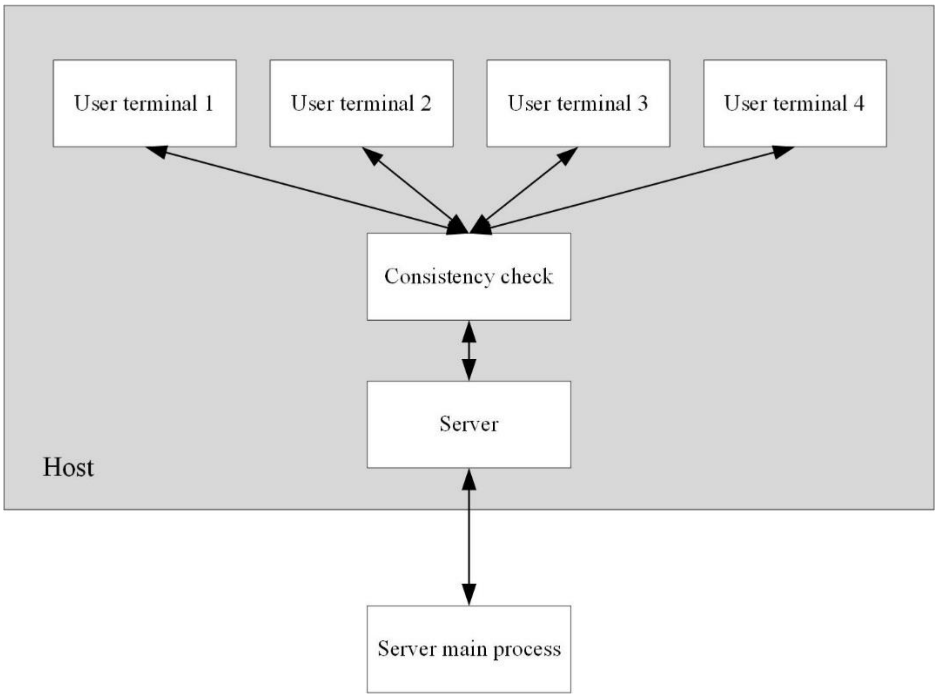


Figure 5. message synchronization mechanism diagram

4. System functions

We build a multiplayer sync air defenses, command and control system used, the system can achieve situational awareness, command is sent, the deployment of troops and shared decision-making of feature , shown in Figure 6 below.

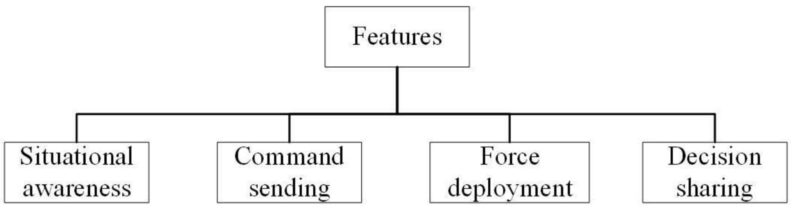
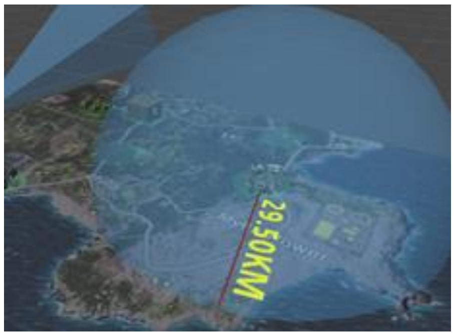


Figure 6. System functions

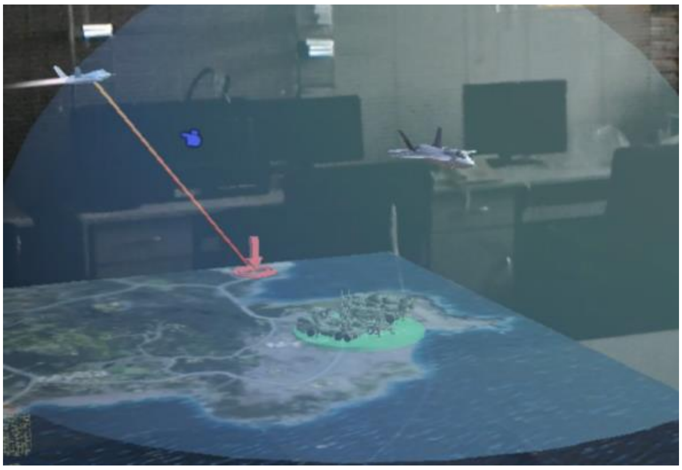
(1) Situational awareness: Thanks to the combination of virtual and real AR technology and real-time interaction, this system can help commanders to efficiently understand the battlefield

information. For example, the deployment of enemy forces, the performance of our weapons, and the terrain of the battlefield are displayed to the commander in three dimensions to reduce the commander 's cognitive load and better control the battlefield situation, as shown in Figure 7 .

(a) Radar range display



(b) Air defence missile fire range display



(c) Display of enemy strike intentions

Figure 7. Battlefield situation information display

(2) Command sending: The commander can click the 3D model of our weapon to generate an operation command based on the battlefield situation information, and control its system to counterattack.

(3) Force deployment: The commander can retrieve the desired force unit model from the 3D model library. Such as various types of anti-aircraft missile vehicles. The commander can hold the gesture to interact with the 3D model and move its position in the terrain to complete the deployment and adjustment of the force unit.

(4) Decision sharing: Thanks to the realization of multi-person collaboration, commanders can see the decision-making situation of other commanders at the same time, and can also show their decision-making to other commanders. Of course, this can only be done after the judgment and command of the conflict resolution machine.

5. Conclusion and Expectation

This system successfully realized the battlefield situation based on augmented reality technology and dynamic holographic display of the combat process, and supported multiple interactive modes such as gestures and voice to command and control air defense operations. This system is of great significance for the improvement of combat efficiency, and at the same time provides a new platform for the planning, deduction, simulation and verification evaluation of the combat process. The system still has deficiencies. The following describes the areas where the system can be further researched, developed and tested:

(1) More natural display effect. Although the system realizes the battlefield situation virtualization and command control, it is limited by the hardware conditions. The display viewing angle is limited, and the display delay problem when multiple users collaborate on the same local area network needs to be improved.

(2) Real-time access to combat information. The true meaning of the intelligent holographic situation display and command and control system should be connected to the battlefield information in real time to provide real-time display and guidance for the commander of the commander. Unfortunately, due to the non-uniformity of the data interface of each weapon system, the function is difficult to achieve .

(3) A more flexible holographic application interaction method. The holographic application developed by the system needs to interact with 3D menus and virtual objects through gaze, gestures, voice, and so on to control the movement of the model. If more intelligent interaction methods such as eye movement control and brain-computer interface can certainly make the operation experience A qualitative change has occurred.

References
[1] Henri D J 1838 The Art of War *New York, NY: Greenhill Press*
[2] Julier S, Baillot Y, Lanzagorta M, Brown D G and Rosenblum L 2000 BARS: battlefield augmented reality system *Nato Sympo-sium on Information Processing Techniques for Military Systems* pp 9-11
[3] Gans E, Roberts D, Bennett M, Towles H, Menozzi A and Cook J 2015 Augmented reality technology for day/night situational awareness for the dismounted Soldier *Display Technologies and Applications for Defense, Security, and Avionics IX;and Head- and Helmet-Mounted Displays XX, 947004 (21 May 2015)*
[4] Jenkins M, Wollocko A, Negri A and Ficthl T 2018 *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry*, pp.272-288
[5] Taylor A G 2016 develop microsoft holoLens apps now *Apress*
[6] Chen H, Lee A S and Swift M 2015 3D collaboration method over holoLens™ and skype™ end points *International Workshop on Immersive Media Experiences. ACM, 2015*
[7] Hockett P and Ingleby T 2016 Augmented Reality with Hololens: Experiential Architectures Embedded in the Real World