Research on Battlefield Situation Display Based on Mixed Reality Technology

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Abstract. Aiming at the problem that the current combat command and control system adopts the two-dimensional information display method, which is not intuitive and easy to overlap, and limits the decision potential of the operator, a method of applying hybrid display technology to battlefield command decision is proposed. By analyzing the application characteristics of mixed reality technology in situation display and command control, using 3D Max, Unity to create virtual models and space environment, writing control scripts such as gaze control and gesture operation under VS2017 platform, and implementing applications based on Hololens mixed reality helmet. The battlefield situation display effect of projecting the holographic image onto the real world surface and the command and control mode of the operator interacting with the holographic image in various forms are realized, which proves the possibility that the future mixed reality technology is applied to actual combat command.

Introduction

With the continuous advancement of intelligent warfare, information will have the characteristics of big data. The traditional information display mode is mainly two-dimensional information such as tables and drawings, and the information amount and display effect are not intuitive enough, which makes it difficult for commanders to quickly and efficiently judge the battlefield situation. Therefore information - entity mapping technology is a revolutionary change of battlefield decision, which to build a virtual equipment system in the information domain of digital battlefield, entity equipment in information domain in virtual form, in the information domain decision will direct drive equipment operation, and the mapping relation based on multidimensional, complicated equipment model and information model. Build an intelligent system integrating virtual and physical space with mutual mapping, mutual guidance, mutual iteration and virtual reality, transformed traditional presentation into a multi-dimensional, all-domain and visible battlefield, which will provide the most direct and powerful support for command and decision-making.

Mixed reality technology provides a new support method for immersive virtual information display and interaction [1], which is a further development of augmented reality technology, and emphasizes the authenticity and real-time integration of real world and virtual world, physical entity and virtual information in users' visual environment [2, 3]. By wearing a mixed-reality display device, users can see the real world and holographic auxiliary information images, and realize multiple interactive modes such as gaze, gesture and voice with holographic images [4].

Mixed Reality and Battlefield Decision Analysis

In the era of big data information for the optimization decision problems need to consider two key points: one is for decision makers, ought to have profound professional knowledge and experience, multiple decision makers should consistent conclusions through the analysis of the collaboration. The second is for technology, need tools in information display, decision aid, remote coordination, such as the provision of effective support and implement closely cooperate with decision makers. At present, the application of virtual reality and augmented reality technology in simulation, training and other aspects has achieved a certain degree of success, but due to some limitations, there are few researches in the field of decision support. For battlefield tactical decision-making, real-time information and
interaction between personnel are particularly important. However, hybrid reality technology can give full play to the advantages of virtual and augmented reality technology and provide significant benefits in decision-making information collection, scheme design and final selection.

The characteristics of mixed reality is virtual continuity between the physical world and digital world [5]. Mixed reality display devices typically include head-mounted displays that present real-time visualizations of real and virtual objects from the user's perspective, in which virtual objects are somehow anchored to the real world and ensure a connection to the physical world. By wearing mixed reality devices, analysts can not only get the latest information in the real world, but also observe virtual images of ground sensors, unmanned aerial vehicle, satellites and other devices, so as to interactively analyze battlefield resources and accelerate tactical decisions. Therefore, using mixed reality technology to implement decision research can increase the dimension of complex information display, improve the interaction between decision makers and virtual objects, and between decision makers.

**Hardware Development Environment**

Microsoft's Hololens represents the most advanced technology in the field of hybrid reality devices. The Hololens mixed reality helmet uses the principle of optical projection to project a four-dimensional light field to the user's retina so that the user can see virtual objects [6]. The user can still see the whole real scene through the lens. At the same time, users can adjust the display focal length according to the visual conditions to get the best optical display experience.

The Hololens is equipped with a number of sensors, including inertial sensors, ambient light sensors, depth cameras and the like. Through these sensors, Hololens scans the real-time information of the current environment, carries out 3d reconstruction of the scene, and tracks the user's position to ensure the geometric accuracy, spatial accuracy and real-time rendering of the virtual 3d model [7]. In addition, the biggest advantage of Hololens over other hybrid reality devices is that it is equipped with independent memory and CPU computing unit, which enables Hololens to complete tasks independently without relying on other computing devices, greatly improving the portability. By configuring holographic processing unit, massive scanning data can be calculated to realize the integration of virtual influence and real world.

Hololens allows users to interact with virtual objects by Gaze, Gesture and Voice [8]. By simulating a ray pointing directly in front of the user, the direction of the ray is controlled by the user's head movement, and the current position of the view point is displayed by a small dot to assist the user in selecting interactive objects. In terms of gesture, Hololens provides users with two gestures: Air Tap and Bloom [9]. The rest of gesture interaction can be defined and written by users themselves. The built-in phonetic libraries of speech interaction are all composed of English, so the realization of natural speech interaction requires the preparation of speech recognition scripts.

**System Design**

**Project Development Process**

Using 3DS MAX, Unity 3D and Visual Studio, Hololens application was developed on Windows10 platform. Use 3DS MAX to draw the required 3D model, import it into Unity for interface design, display adjustment, animation design, etc. Connect Hololens with Unity via LAN, and preview the mixed reality effect in Unity. Unity control scripts are written by Visual Studio in C# language, and when finished, the mixed reality program is imported into Hololens via wire or remote connection.

**Spatial Scanning Information Storage**

Based on simultaneous localization and mapping, Hololens USES information obtained from sensors and cameras to locate itself during movement, and builds incremental maps using the location data. So when entering a new space, mobile users through wear Hololens in space and the observation of space scene of high precision 3 d modeling, unlike the SLAM algorithm based on point cloud or bin,
Hololens model of three-dimensional space based on depth and physical surface reconstruction method can more accurately reflect the real world geometry relationship. Spatial modeling is a gradual process in which the details of the model are gradually perfected as Hololens continues to scan.

**Interface Design**

The interface interaction in mixed reality is different from the traditional two-dimensional graphical interaction in the form of window, graph, menu and cursor (WIMP). Its purpose is to overcome the two-dimensional limitations of traditional interaction and construct a more natural and intuitive three-dimensional interactive environment between man and machine. Currently used in desktop graphical interface of interactive devices, such as a mouse, trackball, touch screen only two degrees of freedom (along the x, y axis translation), and objects in 3d space has the characteristics of six degrees of freedom to move, including the three dimensional space x, y, z axis translation and rotation around the x, y, z axis, due to the increase of the degree of freedom, Windows, menus, figure and the traditional two-dimensional cursor in the 3d interactive environment destroys the space, also make the interactive process is not natural, so need to design a new interface.

The user interface of hybrid reality system includes 3D widgets and 3D models. A 3D Widget is a concept derived from the 2D graphical interface. It is an entity that encapsulates 3D geometry and its behavior. Among them, 3D geometry refers to the appearance of 3D Widget itself, which is generally a rectangular 3D plane that can scale, rotate and stretch in 3D space. Behavior includes interactive control of 3D widgets and other objects in 3D scene and display of object information. There are two types of interaction modes of 3D widgets. One is that 3D widgets, as objects in 3D scenes, can change their position, size, direction and other properties through interactive operations. The second is the content displayed in 3D widgets, which can be interactively operated through gestures, stares and other means. The specific design is:

1. Position of 3D Widget under the viewpoint: as an object in the virtual scene, 3D Widget can be moved, rotated and scaled by the user. This operation can be controlled by gesture signals. In the Widget movement mode, the incremental matrix of hand movement can be used to calculate the movement amount of 3D Widget.

   \[ M' = M_H M_{H'}^{-1} M_{V'} \]  \hspace{1cm} (1)

   Where, \( M_V \) is the matrix of the 3D Widget of the current frame under the view, \( M_H \) is the virtual hand gesture of the current frame obtained by gesture recognition, \( M_{H'} \) is the virtual hand gesture obtained by gesture recognition of the previous frame, and \( M_{V'} \) is the matrix of the 3D Widget of the previous frame under the view.

2. 3D Widget moves with the head: after the user moves the head, the 3D Widget remains motionless relative to the object in the real world. Therefore, after obtaining the posture of the head movement, calculate the offset matrix of the 3D Widget obtained by the head movement:

   \[ M_W = M_H M_{h_0}^{-1} M_{W_0} \]  \hspace{1cm} (2)

   Where, \( M_W \) is the position matrix of the current frame 3D Widget relative to the head, \( M_h \) is the current frame head attitude matrix, \( M_{h_0} \) is the initial attitude of the head, \( M_{W_0} \) is the position matrix of the 3D Widget relative to the head in the initial state.

3. Determination of activation status of 3D widgets: in the face of 3D widgets and 3D models in the interface, interactive operation can only be targeted at the only activated objects. The system judges the interference between the ray formed by the center point of the screen and the direction of the viewpoint and the 3D Widget, and calculates the first object that interferes with the ray, which is the activated 3D Widget.

The 3D model and 3D Widget in the system are composed of battlefield equipment model and decision console. The Unity interface is shown in figure 1. The interface of decision console is composed of radar display, battlefield reality and control button, as shown in figure 2. When making decisions, decision makers first have a preliminary understanding of the situation based on radar...
information and battlefield animation. Equipment models are displayed in a holographic way to help decision makers understand the battlefield state more clearly. Decision-makers can adjust the position of the model to change their battlefield layout decisions. After pressing the control button to give instructions, the battlefield live animation and 3D model will show corresponding changes according to the instructions given to assist decision-makers to quickly obtain real-time information.

Figure 1. Mixed Reality Interface.

Interaction Design

Mixed reality interaction is dominated by gaze and gesture control, supplemented by voice control. Staring in this system is equivalent to a mouse pointer, assisting users to confirm the selected button and adjust the position of the interface and model. By wearing the location of gaze equipment to determine the user's head movement, the human eye can be stable to stay in one spot, but the head can't keep absolutely stationary state, the shake of the head can cause interference to stare at ray collision point, make the fixation point virtual cursor, cause the phenomenon of jitter and fuzzy, so will the user in the process of using it is difficult to accurately select a button or the virtual object, so need to follow the virtual cursor smoothly.

The virtual cursor is used to smooth the movement of the virtual cursor by following the interpolation changes of the head movement. When the user's head moves violently, such as rapidly and widely swinging the head, the following interpolation should be large to achieve rapid tracking. When the user's head moves slowly in a small range, the interpolation amount should be small to suppress jitter and blur.

The position of the current virtual cursor is represented by $P_c$, and the position of the eye collision point in the direction of the user's head is represented by $P_a$. The collection frequency is the same as the frame rate of video, that is, a collision point is collected for each frame, and the value range of $a$ is an integer of 1-30. With video advancing every frame, let $a=a+1$, and when $a=31$, re-assign the value to 1, that is, re-sample the collision point every second, clear the previous data, and avoid the influence of long-term non-correlated sampling points. For data points that have been collected, take the average value of sample positions of all collision points $P_v$:

$$P_v = \frac{P_1 + P_2 + P_3 + \cdots + P_a}{a}. \tag{3}$$

Let $P_d = (P_1^2 + P_2^2 + P_3^2 + \cdots + P_a^2)/a - P_v^2$. Take the threshold value $\alpha = 0.2$ and compare the size of $P_d$ and $\alpha$. If $P_d \geq \alpha$, it indicates that the position of the eye-collision point changes greatly. Take a large interpolation constant $K = 10$ and move $P_c$ to $P_a$ with $K$ as the interpolation quantity. If $P_d < \alpha$, it means that the position of the eye-colliding point changes little. A small interpolation value $P=2$ is adopted to move $P_c$ to $P_v$ with $P \times P_d$ as the interpolation quantity, so as to realize the smooth following of the virtual viewpoint cursor.
In terms of gesture interaction, different gesture responses can be designed through MRTK (Mixed Reality Tool Kit) SDK provided by Microsoft, and different gesture operation types can be created by using the GestureRecognizer function. Using IManipulationHandler class in InputModule namespace and OnManipulationStarted, OnManipulationUpdated, OnManipulationCompleted, OnManipulationCanceled function in the IInputClickHandler class can define different gestures trigger events.

For voice interaction, MicrophoneManager can be edited to enable dictation recognizer, Global Listener function can be written to start Global dictation, and then KeywordRecognize function in ISpeechHandler class can be called to specify the term to be recognized, GrammarRecognize function defines the relevant syntax, and OnPhraseRecognized function can be used to trigger the event after identifying the specified term.

Examples of Application

After the system starts up, the 3D Widget console interface is generated. The decision console can be selected according to the user's gaze command, move freely in any position in the space with gestures, and confirm the fixed position. For the virtual model, the user can also move by gazing and zoom in and out with gestures, fixed on any surface in the space. Operators can simulate battlefield layout, strategy and tactics by interacting with console and virtual model, as shown in figure 3.

Conclusion

The development of mixed reality technology makes it possible to achieve some things that are difficult to achieve in the field of VR and AR. By wearing a mixed reality helmet, 3D information can be obtained more intuitively, and communication judgment in the real world will not be affected, which can effectively improve the efficiency of decision-making. In the next research, we will further explore the decision-making mode under the mode of multi-person cooperation. Mixed reality technology plays an important role in the future development of decision support field and provides a new way of thinking for the command mode in the information battlefield.

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