Study on Big Data Visualization of Joint Operation Command and Control System

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Abstract. As more and more weapons and equipment are connected to the joint operational command and control system, the amount of information generated by the weapons and equipment is also increasing, which has brought tremendous challenges to the commanders and soldiers' ability to make decisions. Based on the concept of "user-centered design", this paper studies the information visualization method of the operational command and control system. The implementation of visualization is divided into three levels: user behavior, interaction architecture, and visual performance. Through the user's task investigation, the logic of interactive architecture, and visual element coding, a joint air defense command and control system interface was designed. After a user test of the interface, the results show that the new design scheme is better than the original program. In this study, task research, design development, and user testing are used to propose a method of information visualization for command and control systems.

Keywords: Joint operation · Command and control
Human-machine interaction · Big data · Visualization · C4ISR

1 Research Background

1.1 The Summary of the Research Background

The number of weapons and equipment connected to the operational command and control system is increasing, and the amount of information generated by the weaponry and equipment is increasing (Lan et al. 2015). This has brought great challenges to the commanders and soldiers' ability to make decisions. The visual design research of command and control system (It is also called C4ISR System) aims to improve the ease of use and aesthetics of the operation interface and reduce the visual burden and cognitive load of the commanders (Lei 2016). By designing and innovating the system's interactive interface, commanders can be better able to command different military types, complete operational tasks, and adapt to multiple usage environments.

The human-machine interaction of traditional weapon systems is a unilateral interaction between man and machine. The new operational command and control system pays more attention to joint operations and needs to combine all types of military, various types of weapon systems, and different battlefield areas. With the

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development of new sensing and communication equipment, joint operations have become synonymous with modern warfare. Joint combat systems combine widely distributed combat units such as sensors, accusation nodes, and weapon platforms. In the process of command and control systems linking combat units, the acquisition, integration, transmission and distribution of various types of information will generate a large amount of data. The results of these data analyses will be presented on the computer screen of the command center. The commander will make judgments based on the data, so the quality of the data visual design will directly affect the efficiency of the commander in making decisions (Liao et al. 2017) (Fig. 1).

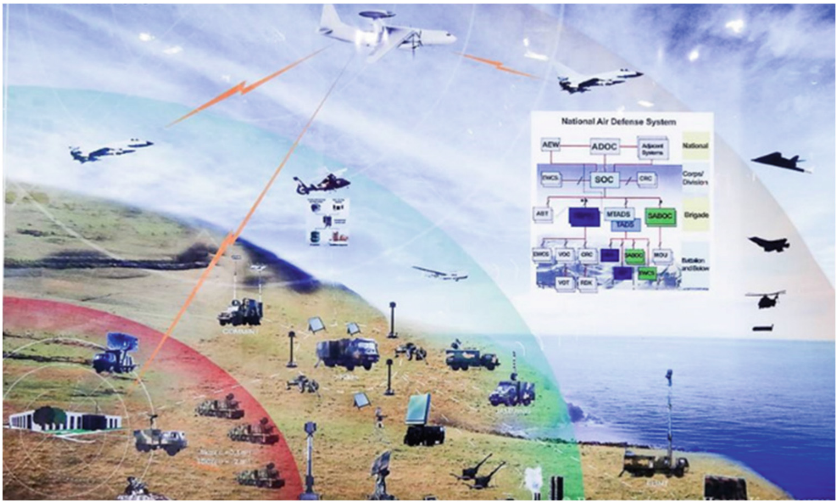

Fig. 1. Structure diagram of air defense system (Picture Resource: http://blog.sina.com.cn/s/blog_856c53b20101fa1f.html)

The most important task of data visualization design of command and control system is to combine information presentation technology with human behavior requirements. The visual design of the command and control system is divided into two main parts: the first part is the design of the digital interface interaction architecture, and the other part is the visual design of the text diagram and the battlefield situation.

1.2 Domestic and Foreign Research Overview

The application of data visualization methods in the field of military operations has a long history. Prior to the invention of the computer, the maps, situation charts, and sand tables used by the commanders were the manifestations of information visualization. In the digital era where computers are widely used, both combat command and control and combat training simulation require the support of various types of data on the battlefield. At the same time, the visualization of large amounts of data has become an important part of combat informationization.

The United States is the proponent of the theory of joint operations in the world. It first built a joint combat command and control system. The National Military Command Center (NMCC) is a strategic command and control system built and delivered by the United States in 1959. The United States has established the main theoretical basis for joint operations and has continuously improved relevant construction goals through practice. At the beginning of the 21st century, the United States proposed the concept of Global Information Grid and C2 Constellation. One important subsystem related to the visualization of big data information is the defense communication system. The system is a defense communication network composed of three subsystems, the Defense Switched Network (DSN), the Defense Data Network (DDN), and the Defense Satellite Communications System (DSCS). It has a variety of information transmission capabilities such as images, data, video, and text. The information communication on the display terminal is mainly through visual methods (Fig. 2).

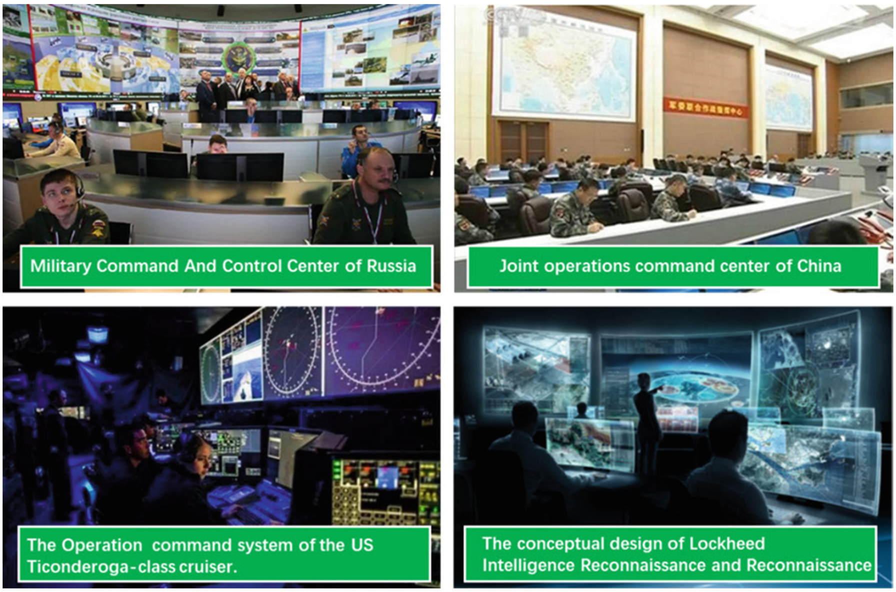

Fig. 2. Command and control system usage scenarios

Russia officially launched the National Defense Command Center at the end of 2014. In the period of peace, it is responsible for monitoring the national security dynamics. Once a war breaks out, the National Defense Command Center will take over the armed forces of the entire country. On April 20, 2016, China exposed the newly established Joint Operations Command Center of the Central Military Commission on CCTV and proposed the requirements for establishing a joint operational command system. Lockheed Martin of the United States demonstrated advanced interactive and display technologies—“21st century intelligence, surveillance and reconnaissance systems”.

The human-computer interaction and interface design research of the command and control system not only needs to solve the system's functional problems, but also needs to improve the experience of the commander and the soldier more, reduce the operational pressure and cognitive burden, and increase the "know-decision-operation" of the commander-in-command. The accuracy and comfort of the process.

2 Interaction Architecture and Information Hierarchy

2.1 Cognition and Design

The design goal of the system interaction architecture is to improve system availability, improve user experience satisfaction, and focus on the fluency and comfort of system commanders during use. The design of the system needs to adhere to the design concept of "centered on the commander and the combatant", and the system design is based on human cognition and human behavior.

The presentation of information visualization content in the interface is constrained by human cognitive ability. Broadbent proposed treating people as a source of a series of processing information, using communication system metrics to consider information flow (Jeff 2014). The information is contained in a series of (n) alternative stimuli. Each stimulus (i) has a probability of occurrence (Pi). By simulating these stimuli, information can be quantified.

$$\text{Information content} = \sum\nolimits_{i=0}^{n} -P_i \log_2\left(\frac{1}{P_i}\right) \text{bits}$$

The amount of information the person's brain is concerned about at the same time is about 125 bits per second. People can deliver about 40 bits of information per second during the conversation. Human short-term memory can only remember 7 ($\pm$) 2 chunks at a time (Gu 2016). Human cognitive ability determines the boundaries of information presented by the user interface. Information that exceeds the cognitive range in a period will result in a decrease in cognitive efficiency. If people are in an emergency, their cognitive ability is still lower than normal. Therefore, data visualization design should give priority to the display of important information. One solution is to use artificial intelligence inference engines to reduce useless information in advance before the results of data visualization are presented. The inference engine can sort the information urgently through algorithm simulation and machine learning, and recommend the most important information to the area that is most likely to be noticed by the commander (Fig. 3).

The system research tasks with "commander as the center" can be divided into three levels: user behavior, interaction architecture, and visual presentation. They correspond to the user's "know-decision-operation" interaction model. This research proposes a research framework for the man-machine interface design of the command and control system, which includes three aspects: user behavior investigation, interaction logic framework design, and graphical user interface design (Shneiderman 2017).

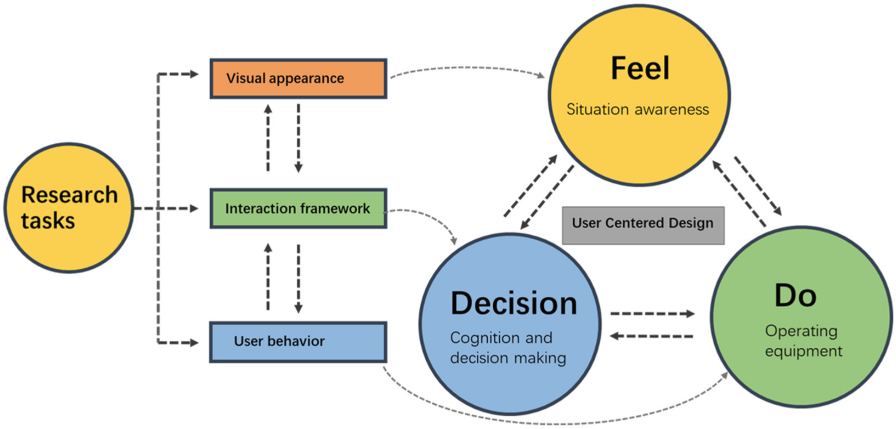

Fig. 3. Command and control system usage scenarios

2.2 Information Layered

Joint operations are the main features of modern warfare. Joint operations are the unified combat forces in a command and control system. Therefore, the interactive architecture of this system is very complicated. Joint operations require the support of information networks, which requires the organization and visualization of large amounts of data, and the conversion of complex big data into information that can be quickly interpreted. Data connection between people and systems, as well as people and equipment, data presentation requires a lot of human-computer interaction design and interface visualization design. Through the classification of information, the commander can accurately find the visual battlefield situation information (Fig. 4).

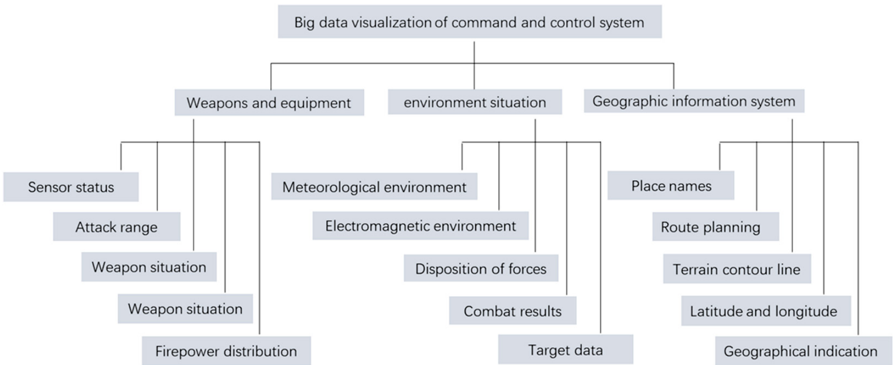

Fig. 4. Data visualization of command and control system

The human-computer interaction design goal of the joint operations command and control system is to integrate image processing, streaming media, data mining, information processing, and visualization technologies, and to graphically design and express elements such as content, relationship, and time in command information. Visualization of the battlefield includes visualizing the battlefield environment, visualizing operational operations, and visualizing intelligence data, which together constitute a command decision support system.

The information visualization method of the joint operations command and control system can be applied to the three stages of the information analysis process, the information collation stage, the information analysis stage and the information presentation stage. The purpose of the collation and analysis of the early stage is to stratify the information and arrange the analysis results according to the importance and urgency. For example, alarm information and security situation information should be placed in an important position, and map situation information should not be blocked by a popup box (Xue 2015).

3 Design Case of Air Defense System

3.1 Modular Design of Interactive Interfaces

The user interface is the space where visual information is carried and is the key content of the human-computer interaction of informationized combat systems. The joint operation command and control system includes various types of software and hardware. The human-computer interaction interface needs to have enough flexibility to customize the functional areas in a modular manner. The human-computer interaction interface should include the system default form and custom layout form. The system allows the user to personalize and divide the role of function settings, the interface is divided into special seat function area, common function area, custom function area and other areas.

The command and control system needs to adapt to different display contents, and it needs to have normative standards and compatibility. The overall system consists of modular, standardized and generalized components. This study used interviews to survey 12 experienced combat system design engineers (Han 2016). According to the conclusion of the investigation and the suggestion of the engineer, the system interface layout is divided into several large modules, and the position between the module and the module can be replaced. Users access the system according to their job rights, and the user's seat will present different modules. At the same time, the system can display a personalized and customized user interface, and the personalized and customized interface can be adjusted according to the task and improve the information utilization efficiency (Fig. 5).

The command and control system should adapt to different display contents, need to have normative standards, and have sufficient compatibility, with modularization, standardization and generalization. In this study, we divided the interface layout into several large modules by investigating the function of the system. A feature plane replaced each module, and the position between the module and the module could be

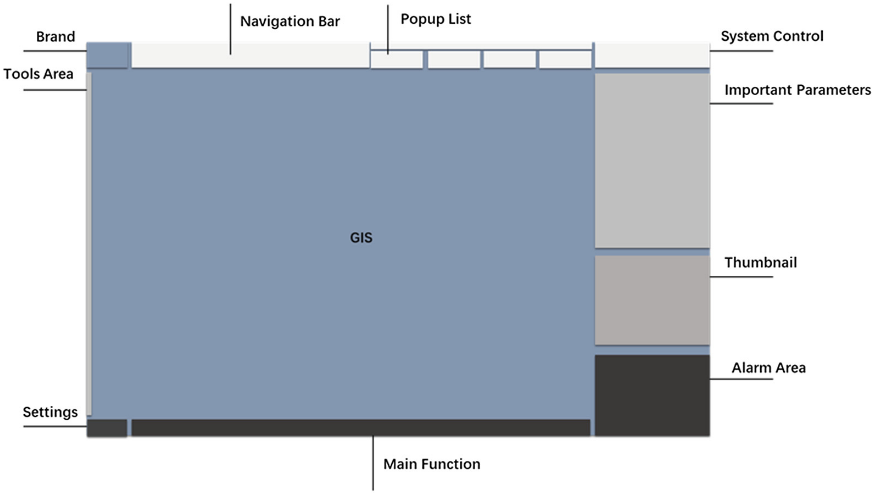

Fig. 5. User interface design framework analysis

replaced. Users of different functions access the system according to the permission, and the user seats will also display different modules. At the same time, the system can display the customized user interface, and the personalized customization interface can use the operational command personnel to layout functional modules according to specific tasks and improve the efficiency of information utilization.

With the increasing importance of air supremacy in the war, air defense command and control systems (Air Defense Operations Center) are becoming more and more important in the national defense system. Many countries place air defense systems on the priority of military development. In fact, the operational command and control automation system is originated from the air defense field. The SAGE Semi-Automatic Ground Environment is recognized as the world's first semi-automatic air defense command and control network (Fig. 6).

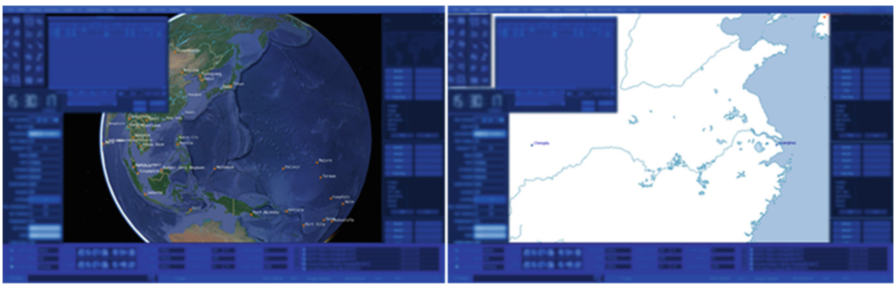

Fig. 6. The concept user interface design of command and control system

In this study, we designed a new interactive interface and situational display for a concept air defense command and control system. We have visualized the battlefield situation based on geographic information systems. The new system uses image processing, streaming media and other technologies to build a new system interface with "functional modularity and data visualization". The new command and control system enables efficient display of data content such as battlefield environments, decision actions, and intelligence information.

This air defense system uses a two-dimensional and three-dimensional map design method. In this system, three-dimensional models have been established for heavy priority areas, weapons and equipment, target buildings, and radar envelope maps. The simulation and rendering of the three-dimensional model enhances the display effect and forms a dynamic, highly simulated scenario that visually makes it easier for users to identify various types of targets. After testing 10 ordinary users, the new system improved the interface quality, reduced the user's cognitive load, and improved the operational command efficiency.

3.2 Battlefield Data Visualization

Situation data mainly includes integrated management of multiple sources of data, real-time modeling of battlefield environmental factors, organization and presentation of various military icons, and display of various weapons and equipment parameters and models. The trend display has multi-dimensional, multi-variable, and multi-type features. The visual expression should use visual coding methods to express the information with the minimum visual element content. The human-computer interaction of the command and control system is also developing toward intelligence. The current system has integrated content screening algorithms that can help commanders optimize the battlefield situation to assist in decision-making.

Plot icons are the main information visualization indicators in the situation. The battlefield visualization system displays battlefield situation information by plotting a variety of military graphic symbols or labels with specific meaning on the map. Plotting icons are widely used in battle deduction and auxiliary command decisions. Situation plotting is an important part of information visualization. The use of military plots needs to be accurate and standardized. Plotting icons requires innovation based on the diversity of tasks. On the two-dimensional map, there are standard military icons that express most of the information. On three-dimensional maps, military plots are rendered using three-dimensional modeling and graphic rendering.

4 Conclusion

The command and control system is the core of multi-arms joint operations. The most important human-machine interaction between the system and the commanders and officers is information communication. The presentation of massive information generated by the operation of various types of equipment requires efficient and accurate visual design. This study applies the "user-centered" design concept. The goal is to improve the user experience of the command and control system. This study divides the visualization into three levels: user behavior, interaction architecture, and visual performance. Based on the user's behavioral characteristics, operating habits, and psychological characteristics, we designed an innovative air defense command and control system design, and proposes a design method of user interface of command and control system. This study tested the method of designing a modular, combinable framework-aided command and control system. Through the three parts of task definition, design development and user test, this study has determined an effective command and control system design process.

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