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Optimal Design of Human-Computer Interaction for Command Information Systems Based on Fitts' Law

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Abstract:

To optimize the fluidity of command information systems in interactive operations, reduce operation time costs, and improve the combat effectiveness of information weapons, this paper selects typical scenarios in the command system as the research object. Based on the unique characteristics of strong interactivity, timeliness, and rigor in related fields, and combined with Fitts' Law, the design strategy is developed to solve the human-computer interaction problems in the original command system interface design. Through analysis and practice, this paper finds that Fitts' theorem can provide strong guidance for designers in the design process of command information systems, and provide methodological guidance and reference for design in related fields.

Keywords:

Fitts' Law
Command information system
Human-computer interaction
Time cost

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1. Introduction

In current warfare, efficiency is the goal pursued by all parties on the battlefield. Efficient intelligence, decision-making, and actions play a decisive role. As a military-specific software, the command information system is a new form of combat weapon in modern warfare. Improving the user experience of the command information system is equivalent to enhancing the combat effectiveness of modern weapons. Fitts' Law, as an important theoretical support in current interaction design, can effectively control the time cost of operators' software operations. It has been applied in commercial software to improve its efficiency. By combining Fitts' Law with typical scenarios of the command information system, this article explores ways to optimize the interface interaction design of the command information system using Fitts' Law, effectively enhancing its combat effectiveness and value.

2. Analysis of the current status of software interaction design for command information systems

Since the 1950s, the US command information system has evolved from C2 to C3I and gradually established the automated command system known as C4ISR. This system tightly integrates various combat units, battlefields, and subsystems in six aspects: command, control, communication, intelligence, surveillance, and reconnaissance [1]. Due to its specific usage scenarios and target users, the command information system differs significantly from commercial 2B and 2C systems in interface design, specifically exhibiting strong operational timeliness, collaborative cooperation, and rigorous task execution.

2.1. Strong operational timeliness

The current battlefield situation, as seen in the Russia-Ukraine war and the Palestine-Israel conflict, differs from WWII's mechanical warfare. Nowadays, battlefield personnel use military software to monitor real-time information efficiently, make quick assessments, and execute decisions, establishing a favorable battlefield position. The command information system, as a core tool in modern warfare, can effectively reduce operators' time and rapidly form combat effectiveness, establishing battlefield advantages, provided that the network remains stable.

2.2. Strong collaborative cooperation

Following the Gulf War, the US proposed various innovative theories such as joint operations, full-dimensional warfare, littoral operations, and air-space integrated operations. These theories explore information-based warfare from different perspectives, introducing new battlefield domains like cyberspace, electromagnetic space, and network space. Modern warfare is evolving towards a multi-domain, multi-dimensional, multi-modal, and multi-service collaborative combat model. The command information system software organizes various military services and functional elements into seat groups, which are simultaneously regulated and configured by higher authorities. Different seats have distinct responsibilities, corresponding information processing, and software interfaces. Therefore, operators of different seats face varied interaction interfaces, which differ significantly in operation methods, complexity, and data visualization, while requiring information exchange among various roles. This emphasizes the strong interactivity of the command information system.

2.3. Strong task rigorousness

In the information age, warfare has shifted from a large-mechanical, small-information era during WWII to an information-dominated, large-mechanical, and big-data combat form. As the brain of battlefield planning, every step in the command information system affects the development of the battlefield situation. Therefore, software designers must focus on the logical efficiency and rationality of operation modes when designing the system's interface. This ensures that operators can efficiently review critical information, schedule tasks, visualize data, and interact with key commands within a limited time. The overall logic and rigor of the system are enhanced by minimizing errors in operators' actions.

3. The guiding role of Fitts' Law in software human-computer interaction

In 1954, Dr. Paul M. Fitts proposed the hypothesis of Fitts' Law after studying human movement characteristics, movement time, movement range, and movement accuracy during operational processes. This hypothesis quantitatively calculates the difficulty of moving to a target selection task [2]. In 1992, Professor Scott MacKenzie from York University presented a variant of the Fitts formula, which simplifies the functional relationship between time (T), target distance (D), and target size (W) [3], as shown in Equation (1).

$$T = a + b\log_2\left\{\frac{D}{W} + 1\right\} \tag{1}$$

The basic content of the law is that the time T required to move from the starting position to the target position is determined by the distance to the target (D) and the size of the target (W). The larger the target and the closer the distance, the shorter the arrival time, and the lower the probability of making errors during movement. Fitts's Law, as a human movement model, has strong guiding significance in ergonomics and is now widely used in the interactive design of various software interfaces to improve software operation efficiency and performance level [4]. The application of Fitts's Law in page design is gradually being valued by designers. Reasonable settings for the area, density, location, and process of elements based on Fitts's Law can improve the operational experience of the page and increase execution efficiency [5]. For example, the application of Fitts's Law in remote education systems has effectively improved the user experience of human-computer interaction in the teaching process [6].

4. Design considerations for Fitts's Law in command-and-control systems

By applying Fitts's Law to the interactive design of the command information system software interface, this article optimizes the basic layout and interaction process of the interface, improving the interactive experience for software operators during system operation, reducing system cognitive errors and error rates during operation, and ultimately enhancing the combat effectiveness of the command information system in terms of speed, stability, and accuracy. Command information systems typically include two types of business forms: situation monitoring and business disposal. This article applies Fitts's Law to the interface layout and system interaction methods of these two business forms to enhance the interactive experience.

4.1. Enlarging guided operation controls to enhance fast, stable and accurate interaction

Software operators need a fast, stable, and accurate operational experience when using the command information system in combat situations to ensure battlefield superiority. To maintain battlefield superiority, system operators need to save time lost in mouse movement, reduce the time spent searching for functional areas, and minimize operational errors during system operation. According to the basic principle of Fitts's Law: the time taken by the mouse to move from the initial point to the click area is inversely proportional to the size of the operation area. The larger the operation area, the shorter the time consumed by mouse movement and the lower the error rate. As shown in **Figure 1**, the area of W1 is larger than that of W2, so the required time T2 is less than T1. Therefore, when interface designers are designing the software interface, they can appropriately enlarge the click area for guiding operational links or buttons, such as increasing the area width when the layout height is limited, to improve the accuracy of clicks during mouse movement.

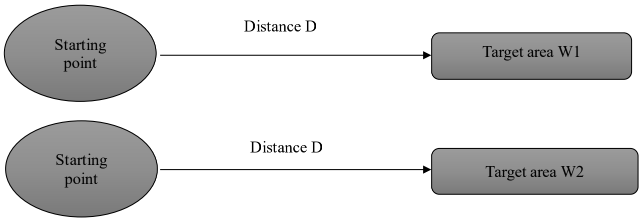

Figure 1. Schematic diagram of the influence of target area size on time according to Fitts's Law.

Typical Scenario 1: Taking the situation interface of a civil aviation system as an example, a large number of real-time targets continuously appear on the situation map. When an alert target appears on the interface (**Figure 2**), the operator clicks on the target of interest to perform a corresponding action. Often, due to the excessive number of targets on the situation map, target icons may overlap, affecting the operator's ability to quickly locate and select a target (see the left image of **Figure 2**). In such cases, designers can enlarge the size of alert targets to 2–3 times their normal size based on Fitts' law (see the right image of **Figure 2**), reducing the difficulty for operators to select targets, shortening aiming time, and improving interaction efficiency.

Figure 2. Comparison of effects before and after enlarging the alert target.

Typical Scenario 2: Consider a data acquisition and processing system. After performing a series of basic data operations such as adding, deleting, and modifying, the operator can save, submit, or perform other options on the results. However, in most cases, operators primarily focus on one specific action. Designers can utilize Fitts' law to shorten the mouse movement time and accelerate information flow. For instance, if the main purpose is to save the data, enlarging the save button (**Figure 3**) increases the clickable area, enhancing efficiency and improving operational command effectiveness.

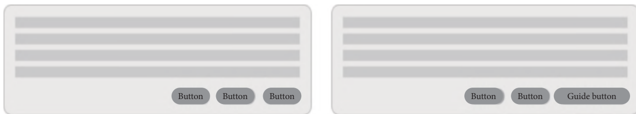

Figure 3. Adjusting button design layout based on Fitts' law.

4.2. Reducing the distance between operation and button areas to lower cognitive difficulty

One of the distinct features of command information systems is multi-seat collaborative operation, where each seat has personalized tasks. Therefore, different seats have varying interaction methods on their command information system interfaces. Software designers categorize buttons based on information architecture, reducing cognitive load and operation-triggering difficulty. According to Fitts' law, the time taken for the mouse to move from the starting point to the click area is directly proportional to the distance of the operation area. The longer the distance, the more time consumed and the higher the error rate. As illustrated in **Figure 4**, distance D1 is shorter than D2, so the required time T1 is less than T2. When designing software interfaces, interface designers can reduce the time lost during mouse movement by shortening the distance for continuous operations, thereby enhancing users' cognitive sense and continuity during software operation and reducing cognitive search time and mouse movement time.

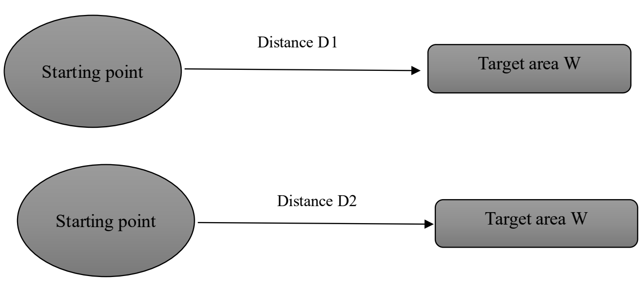

Figure 4. The impact of movement distance on time according to Fitts' law.

Typical Scenario 1: In the civil aviation system situation interface, when users are interested in a specific target, they right-click on the target to access a related operation list menu. Based on Fitts' law, which emphasizes reducing the distance to the target area, when a right-click on a target generates a secondary operation like an operation list menu, the specific operation page should be as close to the menu as possible, with an optimal distance of about 10 pixels (see **Figure 5**). This approach minimizes mouse movement time and helps users quickly locate the desired menu item.

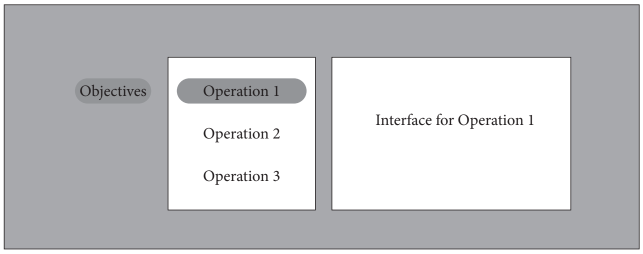

Figure 5. The impact of target area size on time according to Fitts' law.

Typical Scenario 2: In a data acquisition and processing system, drawer controls are commonly used as front-end operation controls for information compilation. Normally, information is compiled from top to bottom, followed by a submit operation before sending the data to the database. Since operators typically fill out data in top-down order, designers follow Fitts' law, which states that operation time is related to distance. Thus, when the operation buttons are placed at the bottom, the mouse is closer to the submit button at the bottom than at the top (see **Figure 6**), saving operators time and improving the operation experience.

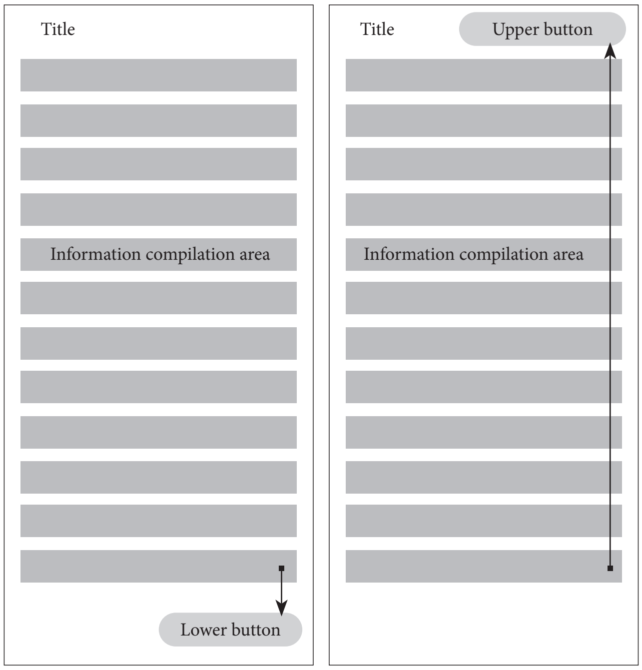

Figure 6. The impact of operation distance on time.

4.3. Making full use of screen borders to improve positioning efficiency

In command information systems, operators typically adopt a dual-screen work mode. One monitor screen is used to display the current battlefield situation and provide real-time monitoring, while the other screen is dedicated to information processing and task scheduling. Different functional orientations lead to distinct data presentations on the left and right screens. Regardless of how the data is presented, it never extends beyond the screen boundaries. Similarly, the mouse, as a tool that guides the operator's gaze, cannot move beyond the screen. Based on this principle, software designers, in combination with the basic principles of Fitts' law, have concluded that when the mouse moves to the edge of the screen, the screen automatically blocks further cursor movement and positions it at the edge area. In software interface design, designers utilize this theory to place important operational areas, such as toolbars, around the perimeter of the screen, facilitating fast and accurate mouse positioning for operators.

Typical Scenario 1: In situation software interfaces, the toolbar is one of the most frequently used controls and is often placed at the bottom of the screen. However, as illustrated in **Figure 7**, when software is deployed in a B/S mode and the browser-based interface doesn't occupy the entire display, leaving space for the system's default menu bar at the bottom, positioning the mouse to the toolbar can become challenging. Positioning would be more convenient and efficient if the toolbar were placed on the left or right side of the software interface. Conversely, in a C/S deployment scenario, the toolbar's positioning at the bottom is not affected by the system menu bar.

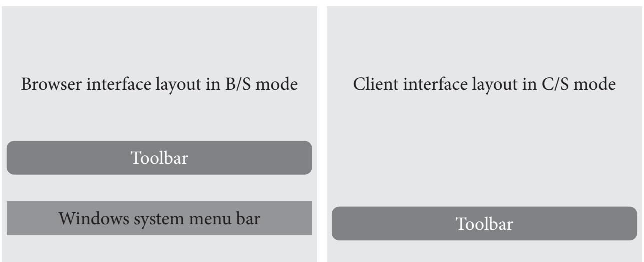

Figure 7. Layout in different modes.

Typical Scenario 2: In business processing software interfaces, tables are a common format for data collection and presentation. Table controls are accompanied by global operations such as adding, batch deletion, importing, and exporting. These global operation areas are typically located in the top left or top right corner of the table. Based on the principle of fully utilizing the screen space, adjustments can be made according to the table's position on the display. According to Fitts' law, when the table is positioned close to the right side of the screen, placing the global operation area in the top right corner makes it easier to locate. Additionally, by utilizing Fitts' law, global operation buttons can be arranged from right to left based on their importance, with the most critical button positioned closest to the right screen border for easier identification and activation.

4.4. Enhancing interaction difficulty to control risks with reverse design

As professional business processing software, command information systems must include basic functions such as system exit and data deletion. These operations are typically characterized by low frequency, irreversibility, and necessity. Therefore, in interface interaction design, designers should fully consider how to avoid these infrequent misoperations that can lead to severe waste of time and delayed responses in battlefield situations. Designers can increase the interaction cost of these misoperations based on reverse thinking from Fitts's Law. For example, they can increase the difficulty of triggering by reducing the size of relevant areas or increasing distances. By narrowing the trigger area or using a drawer style to hide operations, designers can increase the difficulty for operators, raise the cost of misoperations, and improve operational efficiency.

Typical Scenario 1: In the situation interface, the exit operation, from an information architecture perspective, is a global system function like search, settings, and reminders. It should be placed in the same operational area. However, from an interaction standpoint, frequently used functions like search and settings are often triggered by mouse clicks. If the exit button is laid out in parallel with other operational buttons, it can easily cause accidental clicks, leading to unexpected system exits. Through reverse thinking from Fitts's Law, the exit button can be separated from other global operations in the layout. For instance, by clicking on the avatar to trigger a secondary menu and then confirming again, the difficulty of triggering the button is increased, effectively avoiding misoperations.

Typical Scenario 2: In the interface of business processing software, there are often many auxiliary tools for business analysis. Each auxiliary analysis process requires multiple variable data inputs to generate analysis results through specific operational steps. During this process, operators need to modify variables multiple times to form different scenarios. As complementary operations, reset and submit are usually placed together in the layout. However, operators may accidentally trigger the "reset" button while moving the mouse, resulting in the complete loss of previously entered variable data. Based on reverse thinking from Fitts's Law, software designers can separate the two operational buttons in the layout, such as increasing the distance between them or adjusting their positions. This increases the cost of misoperations for operators, improving the interaction experience.

5. Conclusion

As a modern informatized weapon, the command information system plays a crucial role like a brain on the battlefield. A reasonable interface interaction design can reduce user operation error rates, shorten operation time, and decrease the time cost of information circulation. This can enhance combat capabilities to some extent. Fitts's Law, as a theory of human movement models, can be applied by designers in interface design to shorten the time required for mouse movement and target selection, avoiding time loss due to misoperations. In command information systems, designers combine the time and trial-and-error costs of interaction brought by the size and distance of mouse movement to trigger areas in Fitts's Law. They apply forward and reverse thinking in different usage scenarios to achieve corresponding interaction effects. Forward thinking shortens the time cost for users when operating the system, while reverse thinking reduces the error rate when users operate the software. This further improves user operational efficiency, reduces cognitive load costs, and enhances the combat effectiveness of the command information system. Fitts's Law is one of the important theoretical supports for human-computer interaction design research. Rational integration with other design theories can achieve a multiplier effect in interface design.

Disclosure statement

The authors declare no conflict of interest.

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