HI Design Guidelines for Secure and Efficient Air Traffic Control Operations

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Abstract

An air traffic control system is an essential component of today's social infrastructure, providing aeronautical information to the air traffic controllers who support secure and efficient aircraft flight management. For secure and efficient air traffic control system operations, usability is one very important factor. NEC has developed HI (Human Interface) design guidelines to be employed for requirements definition in developing air traffic control systems, along with screen design, in order to unify their human interface. This has also resulted in other related system design developments that support secure and efficient air traffic control operations. This paper introduces our challenges in developing these guidelines.

Keywords

air traffic control, human interface (HI), guidelines

1. Introduction

Demand for aircraft has recently been increasing as a means of efficient transportation and commodity distribution in our society. The aircraft is now an essential vehicle for our society. "Air traffic control system" is a generic name for a system that provides aeronautical information to the air traffic controllers who support secure and efficient aircraft flight management. Air traffic control systems are an essential component of today's social infrastructure.

In order to operate an air traffic control system securely and efficiently, usability is important, i.e. how smoothly air traffic controllers and other operators can operate the system. NEC has developed HI (Human Interface) design guidelines to be employed to develop a system that supports secure and efficient air traffic control operations. This paper introduces the outline of an air traffic control system, followed by our challenges in developing HI design guidelines.

2. Outline of an Air Traffic Control System

In recent years, many movies and dramas focusing on air traffic controllers have been produced, making the details of their work more familiar among ordinary people. As can be seen in these movies and dramas, air traffic controllers are seamlessly surrounded by an abundance of information in order to make the best possible judgments on aircraft flight management.

In general, when people think of an air traffic control system, they might picture an air traffic controller sending various commands to a pilot while observing aircraft images displayed on the screen of a radar control panel. However, the radar control panel is not the only thing that an air traffic controller has to look at. The information that an air traffic controller has to handle includes not only the current positions and heights of aircraft, but also climate conditions along flight routes, traffic congestion and even runway construction schedules. Various flight schedule data, from departure points to destinations, etc., are processed in the system and provided continuously to air traffic controllers. "Air traffic control system" is a generic term that includes a system to process this data and provide relevant information, as well as a radar system to detect aircraft. All of these operations are conducted by staff of MLIT (the Japanese Ministry of Land, Infrastructure, Transport and Tourism), with the exception of some maintenance operations.

Along with air traffic controllers, air traffic services flight information officers and air traffic engineering specialists are also working together to operate the air traffic control system in order to support secure aircraft flight management all day and all night. Air traffic services flight information officers control aeronautical information and coordinate relevant departments, while air traffic engineering specialists monitor the operational status of radars and computers and also conduct their maintenance.

Demand for higher functionality in aircraft is rising year by year. In order to cope with this demand, more functions and systems are being added to conventional air traffic control systems. The more functions are added, the more complicated systems become. Operators are expected to understand such advanced systems and analyze conditions immediately to give the best possible judgment once any trouble occurs.

Up till now, the most demanded characteristics of an air traffic control system were punctuality and immediacy. In addition to these, visibility and readability are essential features of the system and demand for usability is increasing. The data provided by improved usability allows operators to quickly make the best possible judgment.

3. Development of the HI Design Guidelines

In order to enhance the usability of the system, it is important to provide a unified screen design and operating procedures to users. A unified HI eliminates human error due to the misunderstanding to displayed objects or operations. At the same time, it can be expected to help users understand the system even better.

We have developed design guidelines with the aim of unifying the HI of an air traffic control system. These guidelines have contributed to providing improved system usability and secure aircraft flight management, while also encouraging an efficient development process by eliminating duplicated work in the screen design process. The configuration outline and the development process of these guidelines are described in the following section.

3.1 Development Process and Guideline Configuration

The guidelines mainly consist of two documents: "Design Principles" and "Screen Design Standards" (**Fig. 1**).

The Design Principles document states the goal that an air traffic control system should aim for, as well as the policies and principles required to achieve it. It also describes the common elements shared among all staff and customers who are involved in system design and management.

The Screen Design Standards document develops these policies and principles into detailed regulations for screen design and operating procedures. It mainly describes points that developers who design screens should refer to.

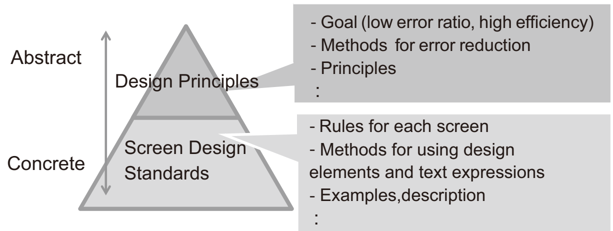

Fig. 1 Configuration of HI design guidelines for air traffic control systems.

For example, when a developer needs to check the reasons for a Screen Design Standards, confirm the effectiveness of a design or even add a new item, he/she is able to refer to the Design Principles and understand the background of the design policies. This will also allow engineers to modify Screen Design Standards based on the original goals and principles.

To develop these guidelines, we first defined the Design Principles and conducted a cross-sectional analysis of various types of current systems in order to determine the details of the Screen Design Standards. System analysis is carried out to identify points to be improved and common factors to be unified, so that rules can be defined for common factors. Instead of simply unifying all screen layout designs, this process enables us to set the optimal rules for each screen based on job priorities, operation frequency, etc. This results in enhanced usability for the entire system.

It is essential to understand the property of individual users and their operations in order to construct a system with high usability. We have, therefore, conducted the guideline development process with the cooperation of engineers who are familiar with the current system and operations, as well as with researchers who are experts on usability and HI design.

3.2 Design Principles

As described in Section 2, today's air traffic control systems demand even higher reliability and efficiency. Our guidelines have been developed to satisfy this demand to support the conduct of secure and efficient air traffic control operations, while developing rules for fundamental principles, policies and screen layouts to achieve unified HI design.

Operating an air traffic control system always involves the risk of causing passengers significant inconvenience, such as through delays or conflicting flight schedules, if the operator misunderstands the system information or makes a wrong judgment. We have provided a methodical countermeasure against such errors, as well as an error classification system considering human perception and cognition, whose effectiveness has been proven via our work in power plant operations. Based on these experiences, we have also made general measures to improve usability and relevant expertise accumulated at laboratories, from which we have developed our policy to prevent critical errors.

We also considered the intuitive human reactions to the appearance of displays and screen operations. Operators perceive various items of information displayed on a screen as visual information to help them understand what is happening and what sort of judgment should be made. Operators then make plans to proceed with their duties by operating various devices. When humans grasp information you can see certain common features in our actions, such as the way of interpreting diagrams, the direction of eye movement, the impression of colors, etc. By optimally using such features, HI design with more intuitive and easy-to-understand processes can be achieved. Our guidelines describe the characteristics of human perception and cognition and provide various measures based on them. We have thereby developed policies for preventing human errors and have developed Design Principles for HI that achieves more intuitive displays and easier operability.

3.3 Analysis of Current Systems

The Design Principles regulate major policies, but they are not detailed enough to carry out actual screen design and provide operating procedures. More detailed rules are therefore required. In order to define them, it is necessary to first understand the users' business, the characteristics of the operations, etc.

Cross-sectional analyses have been conducted using various kinds of targeted screens, such as those presently employed for air traffic control systems, a prototype of a next-generation air traffic control system, etc.

(1) Clarification of context of use and requirements

We consulted developers who know about air traffic control operations and clarified context of use such as operation environment (present system and devices, office lighting conditions, etc.), operators conditions (degree of their expertise, age, etc.) and operation types (specialties, diversity, etc.). Clearly writing down the goal of the HI design and its major premises will enable staff to share and review the procedures to achieve that goal, even those who are not directly involved in guideline development.

(2) Identification of usability issues

Analyses of current screens, manuals, standard design rules, etc. were carried out from the standpoint of usability. While considering the above-mentioned design policies and general rules, we identified inappropriate or inconsistent screen designs and operating procedures across the entire operation.

Ideas to improve the identified issues were examined with a checklist that quantifies the ergonomics knowledge and usability studied in laboratories, etc. Unbiased opinions and expected efficiencies were then shown to and discussed with engineers. During the discussion of the identified issues, we reviewed design purposes and details whenever we found any particular design or operating procedure that may have been employed for clear, unchangeable reasons. This was how we made our decisions on design improvement and consistency.

(3) Identification and classification of common factors

Operators use the system by referring to many different screens for different tasks in order to carry out smooth air traffic control. If consistency of rules for screen design were enforced without considering operation priority, frequency, etc., the system would be far from easy to use. Screens should therefore be classified by the characteristics of each operation according to different tasks, with common rules defined for each classified group of screens.

We discussed with the engineers the results of system analysis, classified operation details and identified common operations in the target system. Then we examined different rules for each classified operation and appointed the areas of the screen where common rules should be applied. For example, certain representative operations for the system are "data input", "item filtering" and "information referencing". We have defined common rules to design the most appropriate screen layout and to provide smooth operations and transitions for each of these representative operation screens.

Even on screens for different operations, common rules are applied to basic operations such as selecting items, displaying error messages, etc. and these common rules are employed throughout the entire system.

3.4 Development of Screen Design Standards

We further examined the design policies and developed detailed Screen Design Standards based on the aforementioned analysis. Text expressions, screen layout, operation flows and prohibited items were determined for different screen types. An example shown in **Fig. 2** describes the rules regarding a data input popup window, one of the most basic screen layout items. Besides this, windows for data reference and information search (narrowing) are classified into different screen layout types, regulated by different rules.

Moreover, as common rules for the entire system, specific use case are described in addition to how to use each component, as well as prohibited items. In terms of how to use the common components, for example, various common components such as menu windows, tabs, list windows and radio buttons are provided, even for simply selecting an item. The rules must describe the standards of component choice, i.e. which

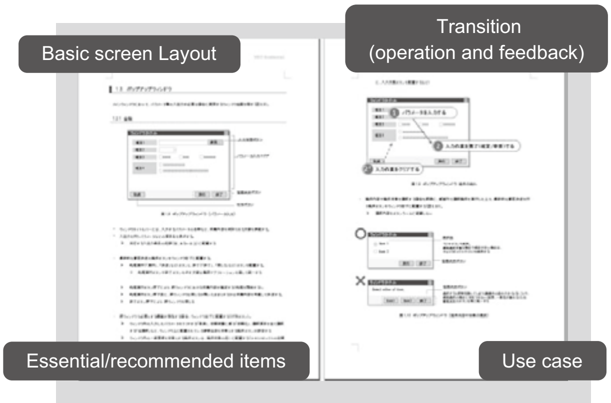

Fig. 2 Sample design standards screen (for popup windows).

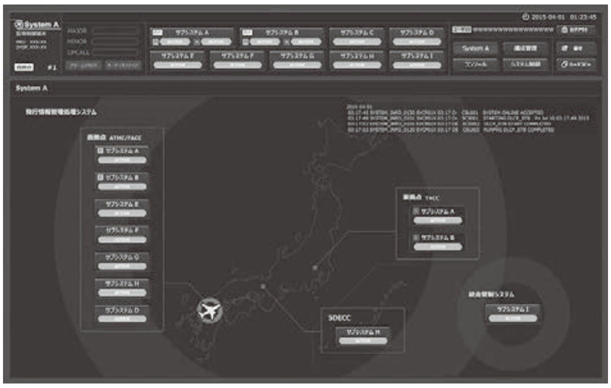

Fig. 3 Example of a screen with the guidelines applied (integrated monitoring screen).

component should be used in which scenario. Along with this description, hints and prohibited items of component usage, as well as detailed schematics for how to use these components, will allow engineers to design appropriate components for appropriate purposes.

A practical example of these guidelines is shown in **Fig. 3**. It is a screen sample for monitoring system operation status in a unified manner. It defines screen layout parameters such as the position of the information to be displayed and the expressions used for notification, so that when a large-scale system fault occurs, the operator can intuitively understand the incident and is able to recognize the influenced area and whether or not it is possible to switch from the active system to the remote backup system. While conforming to the rules of color arrangement and component usage that are defined in the guidelines, as well as considering the target work details and user conditions, it is possible to implement a system that optimally and quickly supports decision-making in a fault occurrence.

4. Conclusion

This paper has described the development process for guidelines to unify the HI design of air traffic control systems. We are confident that our guidelines provide various advantages in different scenarios for air traffic control systems.

From the standpoint of air traffic control operations, unified and intuitive display design and operating procedures across the entire air traffic control system will eliminate simple misunderstandings and eventually prevent human errors. At the same time, these guidelines are expected to reduce operation training times. These advantages can benefit not only a specific operation but also the entire targeted system. From the standpoint of defining system requirements, screen design quality control can be simplified and the amount of reworking can be decreased because detailed standards will be decided and agreed upon with the client at an early stage of system development.

It has been several years since we completed the first version of these guidelines. We are updating them while applying them to various air traffic control systems so that we are able to continuously improve the compatibility of the guidelines to the target operations. We will continue modifying these guidelines in order to contribute to even more secure and efficient aircraft flight management in the future.

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Special Issue TOP