Developing Visualisation Techniques of Tasks in Air Traffic Control Work

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Abstract. Air Traffic Controllers are expected to continue maintaining the safety of the air space and maintaining air traffic flow to run smoothly in complex systems in the future. In this research, we focused on task analysis of air traffic controllers in actual en-route ATC in an experimental activity based on a Human-Centred Design approach for designing the new concept user interfaces. We discuss the method of design to develop a system of human consciousness, especially for Air Traffic Controllers.

Keywords: User Interface Design, Human-Centred Design, Air Traffic Control, Experience map.

1 Background and Purpose

Air Traffic volume is predicted to be increasing in the future. Air Traffic Controllers will also have to handle more complex and heavier air traffic situations in the future. The tasks involved in ATC put heavy demands on the information processing capacities of air traffic controllers. To keep smooth and higher safe air traffic flow, future ATC systems need to be equipped with supporting functions or higher usability interfaces for assisting controllers work. In order to design a future system that can assure higher safety, enhance usability, and support human reliability, the idea of Human-Centred Design processes can help designers in understanding the features in the operations and intentions of the controller.

This research aims to propose a visualisation method to support the task analysis process for designing a new interface for the future ATC system. We believe that a visualisation process for analysis can contribute to the easy understanding of the essential meanings of subjects, when designers design a new interface concept which involves higher usability and efficiency for controllers in ATC work. Understanding user's behaviour is one of the important factors for considering interface design along with the Human-Centred Design (HCD) process.

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2 Approach and Design Process

Air Traffic controllers' work needs to get support from the systems in the future ATM concept such as a 4D-TBO. However, support tools should be user-friendly systems in order to maintain a good relationship between controllers and systems. HCD is one effective method to understand the users' requirements. In order to design a system that can assure safety, enhance usability, and support human reliability under the future concept systems, the idea of HCD processes can help an engineer or an designer in considering the features in the control system operations and the intentions of the controller. "Understanding and specification of a user's usage state" in the "Human-Centred Design process for interactive systems as defined in the Human-Centred Design process ISO9421-210 (Figure.1)". It can be said that this is a key item in the Human-Centred Design that works to visualise the usage state of the product and service being investigated to understand that the user's behaviour is basic for all of the processes of work afterwards. Regarding the observation survey technique, various forms can be taken depending on the purpose and the situation. Because it seeks to investigate how the user is using the product and service. The observation technique can be used to generally investigate a detailed understanding of the usage state and potential needs. However, it requires a lot of time and the workload is huge. In this paper, firstly, we propose an observation survey technique that can obtain survey results of high effectiveness, with a process of Human-Centred Design that can be executed simply compared with conventional techniques.

3 Method of Analysis

Setting of Analysis. To analyze how air traffic controllers work, we built an experiment system for collecting data through simulator experiments (Figure 2). The radar controller and coordination controller, who take charge of en-route ATC, frequently monitor the display of the radar control interface and the data of flight strips, and carry out controlling tasks while exchanging information. For instance, when the radar controller projects the existence of a related aircraft from the radar monitor, a series of instructions from the radar controller are directed to the pilot through communication with the aircraft to avoid conflict. The controllers then input the contents of these instructions into the RDP (Radar Data Processing) system, and input data to the flight strip.

Preliminary Case Study of Task Visualisation. As a preliminary analysis, we tested 5 types of analysis techniques to develop a task visualisation method for analysing Air Traffic Controllers' work as shown in Table 1. The first one in the column is the mapping which focuses on eligible important situations. In this technique, an analyst makes the list of screen shots which were first selected as critical or important situations. And then, they add analytical annotations in each eligible situation on the map by using memo pads. This map can assist in the understanding of the flow of

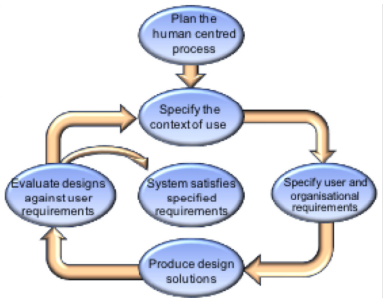


Fig. 1. The Human-Centred Design process ISO9421-210

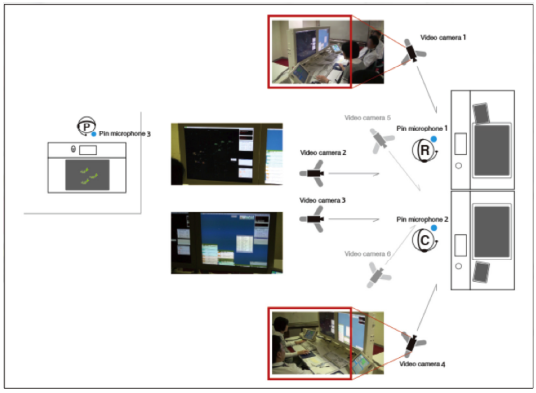
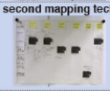


Fig. 2. Setting up a Simulator Experiment

Table 1. Five types of test visualisation methods

	Advantages	Disadvantages
The first mapping technique 	This map can assist in the understanding of the flow of critical situations in the scenario.	To line-up maps along with timeline is difficult because the temporal intervals of capturing screenshots are different.
The second mapping technique 	This map can describe in detail each task.	To make this type of map takes long time.
The third mapping technique 	Trajectories of the cursor can help understand idea the controller' s actions.	To detect the timings when the controller use pull-down menu contents is difficult.
The fourth mapping technique 	This map can assist in the understanding of each aircraft movements along with timeline.	Task symbolisation is not effective support in understanding of the results of task analysis.
The fifth mapping technique 	This map can assist in the understanding of each aircraft movements along with timeline.	The visibility of annotation sentence written by black letters has problems because some of them appear on the black background of the rader screen.

critical situations in the scenario. However, it is difficult to line-up maps along with timeline. Because the temporal length of the screen shot is different in each situation.

The second mapping technique plots the screen shot based on each task onto the timeline. An analyst adds some annotations on these screen shots from an analytical perspective. This mapping can describe in detail each task. On the other hand, it takes longer time to make this type of map. The third mapping technique focuses on the cursor trajectory and pull-down menu contents. In this technique, the screen shot has trajectories of aircraft and the cursor movement by the controller on the radar screen for every one minute in the observation scenario. Each screen shot is lined up

on the timeline on the map. Trajectories of the cursor can help understand idea the controller's actions.

The fourth mapping technique uses symbols of task process to explain the situation instead of annotating. Maps are also divided into every 1 minute screen shot on the timeline as well as the third mapping. We attempt that task symbolisation can assist in the easy understanding of the results of task analysis. The fifth technique is the direct writing annotation. In this technique, an analyst annotates to the screen shots of the radar display which are lined up every 1 minute on the map.

3.1 Preliminary Case Study of Task Visualisation

From the preliminary 5 types of case studies, we found that the screen shots of maps should be displayed for each 1 minute. However, the black background of the radar display shows hard-to-read annotation sentences which in black letters on the map. Therefore, we developed our task visualisation method in which screen shots of radar display are divided into each 1 minute on the timeline of the map (Figure 3). It helps understand the task-flow of the controllers' work. And annotation spaces are also appropriate for writing sufficient information to understand situations. The contents of aircraft are shown by using a memo pad. And an analyst can write annotations such as interview and trajectory of the cursor position on the map which has a white background.

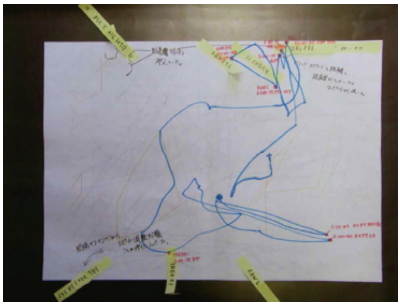


Fig. 3. Prototype of Task Visualisation technique

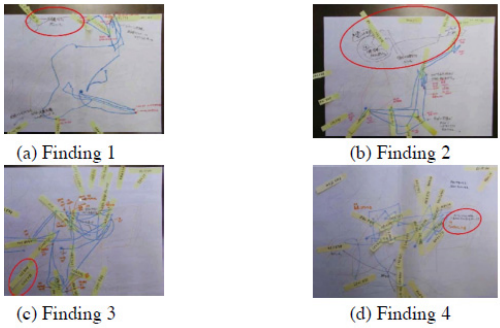


Fig. 4. Simulator observation

4 Case Study of Observation and Analysis

Simulator Observation. As a case study, we observed the working process of a radar controller. We carried out observations during 30 minutes in a time period of main traffic that imposed a certain level of workload on the ATCs. We observed that there are some specific features in the work of the ATCs; in particular, the basis of that work is prediction and instruction, to secure and maintain a safe traffic situation.

Analysis. From the analysis based on our method so far, we acquired the following findings.

1. The Air Traffic Controller starts to think of a strategy of arrival approach order regarding the target aircraft before entering to his/ her handling area. (Figure 4a)
2. The Air Traffic Controller is also aware of aircraft existing in the area to where the controller doesn't move the cursor of the mouse. (Figure 4b)
3. The Air Traffic Controller considers the relative aircraft for crossing as a group. (Figure 4c)
4. The Air Traffic Controller reassigns the route to the aircraft which is getting vectoring instructions after maintaining separation. (Figure 4d)

5 Proposing a Prototype Design of the Radar Screen

From the analysis, we proposed a prototype concept design of the user interface which focuses the spotlight on aircraft related with crossing in the future on a route. Under the conventional systems, Air Traffic Controllers need to search for crossing routes for the relative aircraft by themselves. Therefore, we expect this system will be able to assist in reducing the searching task to find crossing routes for relative aircraft by using our new concept.

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