Tangible interactions in control centres for railway traffic management

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Abstract

A current trend in rail industry control centres is to move towards an increase in the number of digital tools to assist operators. Our observations show that the information used by rail controllers is distributed among different interfaces. Operators must assemble all this information themselves to understand the state of the system. This task is often done mentally, resulting in difficult information sharing and a slower decision process. It is in this search for improvement of the operational centres that we realized a prototype of a tangible touch table presented in this article. The first tests are underway and allow us to have rather positive feedback on this technology that operators are not familiar with. The next iterations will focus on refining the prototype and on experimenting with a larger group of users.

Keywords

Tangible interactions, interactive touch table, behaviour and human-machine integration, control centre, collaboration improvement

1. Introduction

Operations carried out in control centres play a key role in railway traffic management. The operators monitor traffic in real time and resolve disruptions to limit impact on travellers. They also ensure that passengers are properly informed by providing real-time information through the updating of information dissemination tools (applications, screens, sound announcements, etc.). When unexpected events happen, they must modify the planned services on the affected trains, organise alternative solutions, manage the availability of different resources or even call in different maintenance or emergency services, all while guaranteeing passenger safety. A good knowledge of the situation and good communication between operators are necessary to enable them to make a decision quickly. With the increasing amount of data, the multiplication of software and the implementation of more and more automation, it becomes really challenging to visualise and understand what is happening in real-time. On the workspace, composed of several screens, the information is scattered and rarely visually linked. This increases the operators' workload as they need to mentally store and analyse a large quantity of information to assess a situation and predict its evolution, which is time consuming and can lead to errors.

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Figure 1: Left : Control room D and R lines, Paris, France. - Right : The setup composed of a vertical screen and an interactive tabletop using tangible tokens.

Other control centres have been studied in crisis situations to understand the impact of mental load [1]. It was found that design aspects such as layout, procedure integration or coordination between operators are essential to limit mental load.

To overcome these limitations, real-time monitoring systems and sharing tools have been developed. They aim at giving operators the possibility to observe railway performance indicators or to share situations quickly. However, the introduction of these software packages was accompanied by an increase in the number of screens and thus the decrease in operators' attention who spends more time in gathering and memorising instead of using them to make predictions. Rather than working on the tool interface, that is the way in which the information is perceived, we have chosen to explore new ways of interacting with the data.

In this paper, we explore the use of an interactive table with tangible interactions in a case of railroad operation control room. We believe that such setup would make interaction with the network data easier and improve collaborative decision-making.

The use of interactive tangible tables has long been explored in various contexts like data visualization [2], educational context [3] or in control centres [4]. Researches highlight several advantages: (i) they offer a larger display space than a normal screen making it possible to visualize a large amount of data [5]; (ii) they increase spatial memory [6]; (iii) the fact that one can interact with it from the sides of the table makes it possible to have very diverse collaborative work styles: from parallel work in very close collaboration [7].

2. Observations in control centres at SNCF

To understand the current activities and tasks performed in railway control centres, we studied how operators work in 5 different control rooms in France, and conducted around 20 interviews. The aim was to capture the difficulties encountered by operators in monitoring operations and in resolving disruption under tight time constraints. The major difficulties observed and reported by the operators are communication, access to data and a large number of tools.

Operators generally use 6 to 8 screens, mice, keyboards and mobile telephones to communicate with the actors outside the room. They frequently took notes on sheets of paper to store important information. This is a fast and flexible method to collect information, however, it cannot be easily stored and can be lost. These behaviours help operators to build a mental representation of an incident in order to make decisions. However, this can lead to poor collective situational awareness, a cognitive overload and consequently a long decision time.

In addition, railway companies tend to increase the amount of data provided to operators and the growing use of artificial intelligence algorithms to automate control. Observations and interviews show that this trend amplifies the difficulties for operators to visualise data then to build a mental representation and finally to manage disruptions on the rail network.

Communication is both verbal (efficient, spontaneous and direct, but inefficient in a noisy context of intense activity and the information is ephemeral) and written (persistent, but obliges agents to note their decisions). Operators have to be focused on other discussions, memorise oral information, check notifications on screen or group information mentally. All these exchanges of information and these tasks imply a significant mental burden on operators, in terms of memory, perception, process logic and specialisation.

3. Prototype

To explore the use of tangible objects, we developed a prototype of a railway control system workstation that runs a simulation of traffic of one suburban train line. On this system, operators can visualise the traffic state and act on it as they would in a real control room.

Our prototype ran on a horizontal touch tabletop with a vertical large display (Figure 1 - Right). Observations in the control centre showed that operators look up at common screen walls to take real time information. The vertical screen was therefore chosen for information sharing and to promote collective situational awareness. On the contrary, the horizontal screen allowed to position tangible objects and to move them. The displays measure 120x70 cm and the tabletop is at a height of 80 cm. We added tangible interactions on the touch table by using tokens. The purpose of this addition was to start exploring the use of tangible interaction in such context, and to assess the operators' reaction to the addition of this non-traditional input.

The objects used as "tangible" objects are resin hexagons with 3 legs, 7 cm in diameter. We choose this form because it was easy to grab and to manipulate. There are all white but we add a colour label and an icon on the top to distinguish them. Inspired by TouchToken [8], we used different configurations of the legs to make the tangible token identifiable by the system (Figure 3 - Left). The tokens were detected using an infrared sensor frame set up around the tabletop. We then used DBSCAN clustering algorithm to enumerate the objects and to isolate the temporary user's fingers. However, the clustering technique limits the use of objects to stay at least at 1 diameter distant one from another. Finally, the interactions are coded in JavaScript and the display of the media is listed in a parameter file, allowing for many experimental contexts.

Interfaces on both screens have been created according to existing interfaces in control centres for Space-Time Graph (Figure 2 - Left) and Synoptic (Figure 2 - Right). We created the design of the indicators, the cumulative delay graph, the incident notify, the task list, buttons and labels on objects. In the same way, interactions were imagined and designed in the context of scenarios for future user testing without scientific justifications. As part of our approach to think about the use and usefulness of tangible objects, we have introduced two initial interactions. The first one allows to navigate thought the time while the second one allows to explore the software

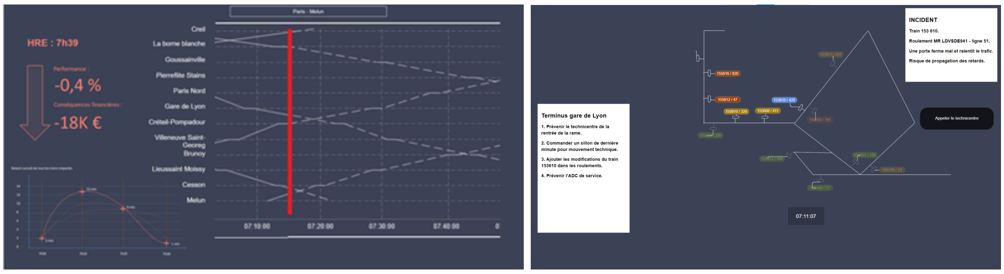

Figure 2: Left: Vertical screen to show charts and figures. Right: Horizontal screen on the touch table.

functions and apply decisions.

Users can explore the consequences of their actions on the traffic. For that, they put the *time-object* (purple label) (Figure 3 - Right) on the table and screens change colour to better capture the difference between the present state in black (Figure 2-Right) and the projected situation in blue (Figure 3-Right). They can navigate through time in the future by rotating the object and see short and long time (3 min to 2-3 hours) consequences on both screens to make decisions. The clockwise direction allows to go into the future and the counter-clockwise direction allows to go backwards without going beyond the current time. This interaction is reminiscent of the movement made to set a timer. On the top screen (Figure 2-Left), a graph represents trains in stations over time. Full lines represent the past and dotted lines the provisional. The red line is to show the current time. By rotating the object, the graph moves to allow operators to see the situation in the future. On the bottom screen (Figure 2-Right), trains are reflected on a railway diagram over their positions. By rotating the object, trains move in the diagram to show their predicted positions. The label colours represent the train delays and the impacted train is shown with a blue label. By lifting the object, the operator can instantly return to the real world. In this case, the advantages of the tangible interface are to allow new information to be displayed and simply removed from the screen.

Operators can also use a *menu-object* (orange label) (Figure 3-Right) to explore the different procedures proposed by the system they can use to answer to a specific situation. When they put that object on the screen, a menu appears next to the object. When moving the object, the menu follows it. Turning the object in the clockwise direction allows to go down in the menu and the counter-clockwise direction to go up. We were inspired by physical knobs that were used to select a specific option or set parameters that can be found, for instance, in old power plans control rooms. Depending on the chosen procedure, the list of tasks to be performed on the bottom left of the screen is modified and the numerical consequences are presented on the left of the top screen (Estimated time of recovery, cost, % and delay rate). Once the procedure is chosen, the operator presses with their finger the select button (green).

4. Results

In a feedback session, we asked two operators, each of them in a solo session, to monitor a simulated traffic using our prototype. After a few minutes, the system simulates an incident (in

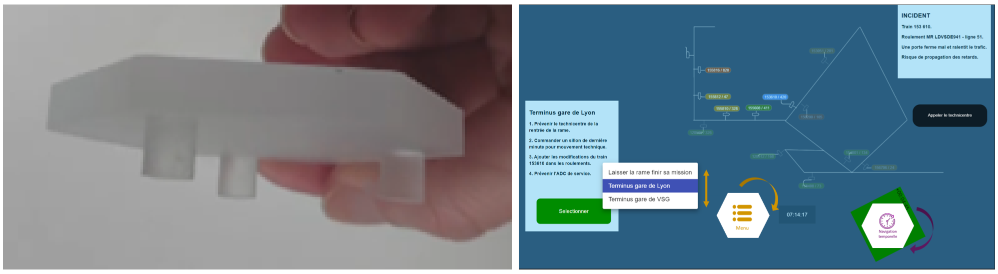

Figure 3: Left: Tangible token used in this experiment. Right: Horizontal screen on the touch table with 2 hexagonal objects placed on it.

this case, a defective door on one train) which triggers a notification on the participant's screen. They had to explore the different options to solve this situation and their impact on traffic and then select the one they thought was the best.

First feedback of two operators are very positive. They found the use of the prototype to be fluid and the proposal of 3 solutions to respond to the incident is well received by operators. However, their first feedback are that they are not accustomed working with numbers (on the left of the top screen) so they did not use it, they use the visualisations because they're used to use it and they analyse them quickly. Regarding the tangible, use of objects is not intuitive, users needed an explanation about how to move objects and why. This can be explained by technical problems that created a few seconds delay between the user's movements and modifications of the interface. One solution would be to train operators with tangible tokens only before using the full system. This will allow them to get used to potential latency. However, after a short presentation, they found tangible objects relevant. Especially, navigation through time which facilitates the study of the space-time graph and consequences compared to the current mouse/keyboard interaction.

5. Discussion and conclusion

This paper proposes the integration of tangible interactions to improve decision-making in railway control rooms by acting on the interaction with data. We implemented a functional prototype using a tabletop and tangible interaction for time navigation and decision application and performed feedback sessions with operators.

Our first results suggest that tangible interaction is a promising direction and future iterations will focus on exploring the design space of such interactions for control room tasks. We will evaluate different interaction techniques and study how they can assist the operators in interacting with the system and the data. We will also explore the use of different technologies to understand their benefits and limitations and explore new gestures.

We believe that this work will contribute to prepare the future of the railway industry and that its usefulness will extend to other mobility systems. Other industries with complex management centres and organizations could benefit from the advantages of this prototype.

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