Understanding Large Display Environments: Contextual Inquiry in a Control Room

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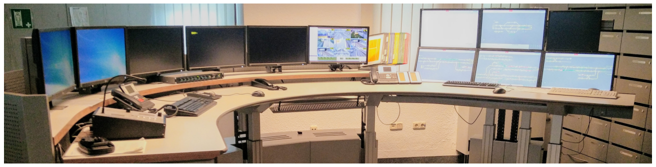

Figure 1: A six screen setup for train routing plus an additional six sceens for safety critical maneuver.

Abstract

Research has identified benefits of large high-resolution displays (LHRDs) for exploring and understanding visual information. However, these displays are still not commonplace in work environments. Control rooms are one of the rare cases where LHRD workplaces are used in practice. To understand the challenges in developing LHRD workplaces, we conducted a contextual inquiry a public transport control room. In this work, we present the physical arrangement of the control room workplaces and describe work routines with a focus on the interaction with visually displayed content. While staff members stated that they would prefer to use even more display space, we identified critical challenges for input on LHRDs and designing graphical user interfaces (GUIs) for LHRDs.

Author Keywords

Large High-Resolution Displays; Multidisplay Environment; Control Room; Contextual Inquiry.

ACM Classification Keywords

H.5.2 [User Interfaces]: Graphical user interfaces (GUI).

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Introduction and Background

For the last four decades, research has explored the design space and the advantages of LHRDs and multidisplay environments. However, the usage of LHRDs is still not commonplace and limited to specific areas. Today, we see LHRDs as public displays, mostly displaying non-interactive advertisements or guidance information (e.g. [9]). Slowly, LHRDs become popular as interactive information screens in museums (e.g. [10]) and showrooms. Furthermore, we see LHRDs used in research labs (e.g. [1, 12]). In contrast, we observe only slowly increasing screen sizes for regular working environments. Control rooms are one exception. There, LHRD workplaces are commonplace. Thus, control rooms provide the unique opportunity to understand how LHRD workplaces are used outside of academia today (e.g. [15]). Thereby, we can identify challenges and design implications for LHRD workplaces. Here, we present the results of a contextual inquiry of a recently modernized public transport control room in a major south German city.

Contextual inquiries are widely used to understand workflows. Different aspects of the work performed in control rooms have been studied in detail. Heath and Luff [4] highlighted the combination of collaborative work and use of multimedia technology. They presented a detailed and well-structured description of work processes and tools used with a focus on collaboration in underground control rooms in London. Christer Garbis [3] extended the work on ethnographical observations of work performed in control rooms with a focus on shared cognition. In particular, he highlighted the importance of shared displays for staff members. Wendy MacKay [7] analyzed the importance of paper flight strips in air traffic control. Thereby, she highlighted the challenge to improve safety critical systems and argueed for augmenting tangible paper strips, instead of replacing them with a fully digital solution.

Müller et al. [8] observed a trend from tangible controls to digital and graphical controls. Hence, the authors recommend using a combination of tangible controls which can be flexible placed on touch displays. Domova et al. [2] argue to provide haptic feedback though input devices such as the mouse or slider knobs. In contrast, Heimonen et al. [5] proposed to improve human-computer interaction in control rooms through gestures and speech control. Prouzeau et al. [11] presented a system to visually compare life road traffic data with simulation data on a touch-enabled LHRD. The presented prototype changes the user's body posture form seated to standing and walking.

Contextual Inquiry

To build an understanding of how work in a modern public transportation control room is performed and how interactive technology is used, we conducted 18 hours of observation. Furthermore, we interviewed staff working in the control room with a focus on workflow and used tools. To avoid influencing the staff during their work and due to regulations, we did not audio or video record our observation sessions. Instead, two researchers observed all actions during the sessions and took notes and sketches. We conducted the observation during three sessions. One session was on a Wednesday morning from 6:00 to 12:00, including the morning rush hour. The second session was during regular daytime on a Friday between 10:00 and 16:00. The last session was during a night shift from Saturday 21:00 to Sunday 3:00. During this shift, the staff members also monitor maintenance work in the field.

Findings

We grouped our findings based on the observations in the categories physical arrangement of the work environment, content alignment on displays, and input techniques used to interact with digital content in the control room.

Physical Arrangement
The analyzed control room had eight working desks. Two tables were for the tram signal tower. At one desk, one assistant scheduled the tram traffic, at another desk, one assistant scheduled the bus traffic. At another desk an assistant coordinated all information channels for passengers in vehicles, on stations and using online information systems. Two additional desks were for major events and training sessions. The last desk was the general coordinator, managing all staff in the control room. All desks were oriented towards a large projection screen. This projection screen is used to display live-views of surveillance cameras or urgent information to all staff members.

Every workstation desk was curved to provide easy access to all areas of its surface. Each desk was automatically height adjustable to allow staff members to adjust the table height to their preferences. Thus the desk height and the height of the displays could be adjusted separately. Furthermore, this allowed staff members to stand and sit during their work. The possibility to work in various body postures was used by most staff members regularly. Thereby the preferred posture is also depended on ongoing actions. In emergency cases the demand for coordination between staff members increased. Then, all staff members worked in a seated position because this allowed all of them to look above the displays and have face-to-face interaction.

Every working desk was equipped with six regular office screens. Each screen had a diagonal of 24 inches and full HD resolution. All six screens were in landscape mode and horizontally aligned. In a regular working position, its not possible to focus on the whole display space at once. To change the focused area, staff members had to rotate their head or body. Furthermore, every desk was equipped with a phone and a microphone for radio communication with drivers. The two tram signal tower desks were equipped with six additional screens for train protection. These screens were also oriented in landscape mode but aligned in a 3×2 grid (see Figure 1). The software and screens used had to the fulfill high safety standards regarding reliability. Furthermore, the train protection system had to be isolated from all other systems due to security reasons.

View Arrangement
Normally one view was displayed in one application window in full-screen mode on one screen. We did not observe, application windows spread out over multiple screens or the entire display space. Thereby, the single screens were used as containers to order different views. Furthermore, staff members could switch the displayed views between several predefined scenarios. By default, a set of scenarios is provided. Additionally, they could define personal scenarios, which fit their workflow better. Besides the large visual output space, audio notifications were used for events triggered by applications that were not on display. When staff members opened new views, we observed that the views sometimes appeared in arbitrary positions. This created additional demand to search for the view and move it to the desired position. In interviews, staff members stated that they would prefer having even more display space. This would allow to have more views on display at the same time without switching single views or full scenarios.

Input Techniques
To perform input, staff members used one computer mouse and a regular keyboard. The working desks for the tram signal tower had an additional mouse and keyboard for the train protection system. Every workplace was equipped with an additional keypad to switch between the different scenarios. This keypad allowed warping the cursor to one of the six screens directly. However, it was not obvious to the staff

members where on a particular display the cursor would appear. Hence, this function was rarely used. Regularly, the staff members moved and clutched the mouse until the cursor was at the desired position. The high number of independent software systems often created situations in which staff members had to interact with multiple application windows at once. In interviews, the staff members explained that they would like to have separate input focus for mouse and keyboard, because after clicking in one application they forget to reset the input focus before performing keyboard input for another application window.

Additionally to a high number of automatically logged events, we observed some events which are reported or noted on paper. This had the advantage that this reporting could performed without requiring screen space or input focus. Furthermore, the paper-based notes could handed over quickly to another staff member.

Discussion

Our observations indicate challenges for the general design of LHRD workplaces and GUIs for LHRDs. We classify these challenges into the following categories: input techniques, physical display space, and content management.

Input Techniques

Our observations show challenges in performing input on larger display spaces. The large display space creates a high physical demand when moving the mouse cursor across the display space. Over one decade ago, Robertson et al. [13] described the challenge of long cursor distances and cursor loss when using LHRDs. The additional keypad to warp the cursor to a specific display does not solve this challenge, in particular, because the exact warp position is not obvious to the user. Visually searching for the cursor even on a smaller area, such as a single regular office screen, causes a high distracting demand. One solution to replace the cursor would be enabling direct touch. In particular in this scenario, were the whole display space is in arm's range, touch input could improve the interaction. More generally, eye tracking could support pointing tasks on LHRDs [6]. When using eye tracking, the advantage is that the distance between user and the display is not restricted. In the next step, it is important to refine research prototypes to techniques used in practice.

The possibility to have a large number of application windows displayed at the same time creates the need to separate the input focus of the different input devices. For staff members at the control room would it make sense, to be able to lock the keyboard focus to one application, while working in other application windows with the mouse.

Display Space

In comparison to previous work [3, 4], the personal display space per desk has increased over the last decades. Today, the standard desk in control rooms are equipped with an LHRD. Furthermore, the commonly used shared diagram displays have been replaced by fully flexible projection screens. Also, other output channels, such as audio notifications are used. Nevertheless, staff members stated that they would prefer to have even more display space for each desk. This would allow seeing more scenarios without manually switching them. Hence, the staff members perceive physical navigation less demanding than virtual navigation. This is in line with Ball et al.'s [1] results, showing that participants were able to extract information faster and with less effort when navigating physically, instead of virtually changing the viewpoint. Furthermore, the request for more display space indicates that humans can interact with very large visual spaces without being overwhelmed.

Managing Content
In the control room, we saw that one application window was displayed on one single screen. This shows that staff members make use of the physical display design to organize their screen space. Wallace et al. [14] showed that participants could extract information faster when utilizing bezels to divide the display space. The design of GUIs for LHRDs should take physical bezels into account. For setups with bezel-free screens, the GUIs design should provide visual support to divide the display space.

When working with LHRDs, the visual position of an event becomes essential. Staff members in the control room reported that application windows did not appear at the expected position. When a manually opened application window or dialogue box appeared outside the focus area, the user has to search the GUI element visually. It could cause safety consequences, if the user dismisses an important notification triggered by the system. Hence, carefully designed notification and event systems have to be developed. Therefore, it is important to understand how users interact with the visual space provided by the LHRD. First, a detailed understanding of human visual perception on large visual areas is required. Furthermore, LHRD systems should make use of the user's head and gaze position to detect the user's visual focus area. As a first approximation the input focus could be used as a position for notifications and displaying new dialogues and application windows.

Conclusion
In control rooms, complex processes are monitored and managed. Staff members have to make system-relevant and often safety-critical decisions. Thereby they are supported by a large amount of information displayed on LHRDs. The usage of large display spaces enabled us to observe common work practices and identify challenges for interacting with LHRDs. The findings of our study show that adequate input techniques for LHRDs have to be developed and moved from research prototypes to practice. Furthermore, GUIs have to present relevant information on the best spatial position to be recognized by the user.

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