Design guidelines for multi-display environments in command and control centers

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Simone Mora
SITUATIONAL AWARENESS & COMMAND
Outline

• The Apollo mission control room
• Role of Command and Control centers
• Methodology
• Design space
  • Public - Personal
  • Static - Dynamic
  • Analog - Digital
  • Physical - Virtual
  • Mobile - Fixed
• Design guidelines
• Conclusions
Bibliography

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Public displays

Group displays

Personal displays
DYNAMIC

STATIC

SEMI-DYNAMIC

DYNAMIC

STATIC

STATIC

DISPLAY

NTNU
UK Nuclear power plant CR (1950s)

Massachusetts Bay Transportation Authority CR (2010s)
Design dimensions for displays in control rooms

MOBILE - FIXED

PUBLIC - PRIVATE

ANALOG - DIGITAL

PHYSICAL - VIRTUAL

STATIC - DYNAMIC
Outline

• The Apollo mission control room
• Role of Command and Control centers
• Design space

• Design guidelines
  • Balance information on multiple displays
  • Design for ecologies
  • Leverage the constraints
  • Avoid information overload
  • Design for tangible displays
  • Augment static displays
  • Introduce incremental changes

• Conclusions
Balance information on public, private, and group displays
Design for ecologies of displays and “layers of seeing”

Leverage the constraints of displays
Each person is an implicit information display
The technology in the control room The Bakerloo Line, London Underground is currently undergoing extensive modernisation. By 1991 signalling will be fully computerised and monitored from the Line Control Room at Baker Street. At the present time, the Bakerloo Line Control Room houses the Line Controller, who coordinates the day-to-day running of the railway and the Divisional Information Assistant (DIA) whose responsibilities include providing information to passengers through a public address (PA) system and communicating with station managers. Figure 1 shows the general layout of the Control Room.

The Controller and DIA sit together at a semicircular console which faces a tiled, real-time, hard line display which runs nearly the entire length of the room and shows traffic movement along the Bakerloo Line (from the Elephant and Castle to Queens Park). The console includes touch screen telephones, a radio system for contact with drivers, the PA control keys, and close circuit television (CCTV) monitors and controls for viewing platforms (see Figure 2). Occasionally a trainee DIA or a second controller will sit at this console. In the near future, two or three signal assistants will sit at a similar console next to the Controller and DIA (see Figure 1) and personnel will also have access to monitors showing real-time...
Avoid information overload
Figure 3: The Vehicle Availability Map (VAM) which lists ambulances by regions. Ambulances active on emergencies are here shown with their IDs against a black background. Ambulances on urgent calls are shown against a grey background. Ambulances on standby are shown 'flashing'. Available ambulances are just depicted by their ID. See main text for further explanation.


Design for tangible displays
INTRODUCTION

Figure 1. The coMAP system running on a Samsung SUR40 with Microsoft Pixelsense tabletop surfaces.

Interactive displays, such as the support of several tracking techniques were considered under design criteria typical to and thereby avoid inconsistencies.

"Madgets" [14] virtual control elements regarding accuracy and overall interaction time. Illuminated Purpose" (SLAP) Widgets. The widget set consists of systems is presented by Weiss et al. [3]. An example of tangible control elements on interactive tabletops is shown in Figure 4 (center, bottom). The visualization of each concept has a passive numerical value (top left) and a but 5), which includes the actual value of the process variable as a caused by the lower and upper constraints of the guide slot. Setting the maximum slider control enables operation wi.

Both element types of the tangible-object concepts (Figure 4) inherit the handling qualities of the respective model styles of their model. This also includes the physical constraints at the original physical constraints. For both element types level and minimum value is accompanied with a perceivable resistance to the physical constraints of the guide slot. Setting the maximum actuator that are described in the DIN document. For both actuators are operated via a rotatory handle with continuous amplitudes. While this limits quick operation (in particular for the control element as defined in DIN EN 894-3. Rotatory control techniques were considered under design criteria typical to and thereby avoid inconsistencies.

The hardware chosen offers specialized functions, such as drawing of offer a speedy interaction in a tangible way. Moreover, they emphasize the direction code. In the sense of readability offers information layers located within the framed perspective on control room design.

The system offers generic GUI control markers that indicate unit dependent freeform areas. The visualization and the current value is adjusted accordingly. Due to visualization of each concept has a passive numerical value (top left) and the slider control (bottom) element.

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Augment static displays rather than virtualise
Sociologists, if different groups of sociologists, are more interested in the social and historical context of the work. Harper et al. [1991] and Hughes et al. [1992] emphasize how the context of the work is essential for understanding both the controllers' activities and the role of paper flight strips. For example, Bressolle et al. [1995] have demonstrated that, when traffic levels increase, controllers speak to each other less often and write more on the strips. Poirot-Delpech [1995] argues that strips form an essential part of a controller's identity and play a symbolic role as the physical objects representing the otherwise invisible aircraft in the air. Hopkin [1995] studied how flight strips have evolved over the past half-century, allowing the controllers to flexibly incorporate on-going changes in the air traffic control system. We did not see evidence that these social and historical accounts were considered in the design of the new systems.

Each of these perspectives has limitations. Software engineers are primarily interested in the new benefits offered by the systems they design; it is difficult for them to assess the importance of intangible safety features built into the existing system. Cognitive ergonomists who seek to find and prevent errors may undervalue successful work practices and underestimate the risks involved in changing them. Sociologists may offer many interesting insights into the context and practice of air traffic control but, with a few exceptions, e.g., Hughes et al. [1992] rarely influence system design. There is, of course, another important perspective: that of the air traffic controllers themselves.

Air traffic controllers like paper flight strips. The interface is familiar, easy-to-use, helps controllers instantly understand the current state of the traffic and lets them communicate without interrupting each other. For example, controlled by that position; when the light flashes, it indicates not only that a pilot is speaking, but also on which frequency and sector. Controllers glance at the quantity of strips and corresponding level of annotations to get a sense of the traffic. For example, during a storm or when the military has closed a section of the air space, controllers must reroute all aircraft, which results in an easily identifiable pattern of annotations on the strips. These visual cues rely on the human visual system's use of focused and peripheral views. New systems that try to place the same quantity of visual information into a single, focused display are likely to be more difficult to read and thus less safe.

Tactile cues are subtle. Running one's hands along the strips helps to mentally count them, even when looking elsewhere. We watched student controllers staring at the radar, trying and failing to insert a 14th strip into a column that held only 13. Senior and qualified controllers never make this mistake.

Controllers share a small physical space, which helps them monitor each other's activities. Figure 6 shows two controllers simultaneously annotating two different strips. Each is aware of the others' annotation and will check it at the next opportunity. At night, when all sectors are combined into two control positions, the east and west controllers always sit next to each other. This is an important safety check, as they keep each other company and ensure that neither falls asleep.

Peripheral awareness helps explain a related phenomenon among team members. In light-to-moderate traffic conditions, members of the team who are not assigned to a particular position chat with each other near their team's working control positions. (In contrast, members of the team physically leave the control room during official breaks, after ensuring that the relief team is fully operational.) To external eyes, they appear to be off-duty and perhaps even annoying their "working" colleagues by generating extra-. 

Aim at incremental changes in design
Conclusions

• Balance information on public, private and group displays
• Design for ecologies of displays and “layers of seeing”
• Leverage the constraints of displays
  • Each person is an implicit information display
• Avoid information overload
• Design for tangible displays
• Augment static displays rather than virtualise
• Aim at incremental changes in design
Thanks!

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