Designing Displays for Mobile Decision Support

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Mobile context aware decision support systems have the potential to provide workers with the information they need, when they need it. The design of such systems must take into account the organisation of information, the activities of the worker, and the wider sociotechnical system if they are to work effectively. Cognitive Work Analysis (CWA) has been applied extensively to the design of decision support systems, as it gives us a framework for structuring complex information spaces, which is a major component of designing a comprehensible and consistent decision support system. This approach can be paired with ecological interface design (EID) for mapping these information structures onto representations within the interface. These approaches have been developed for traditional interaction scenarios, particularly control room interfaces. The display limitations and task scenarios associated with mobile workers differ from those related to control room operators. In this paper we look at mobile context aware decision support, in an industrial setting. We discuss how the display restrictions of mobile devices can be countered by the potential for automated navigated through location awareness and the repercussions this has on the users understanding of system state.

Information representation, decision support, cognitive work analysis, mobile display design.

1. INTRODUCTION

Mobile context aware systems are the focus of much research and development activity at the present time. Within an industrial context, there is much interest in such systems as a means to supply mobile workers with access to system information and functionality. While automation and increased complexity have encouraged a move towards more centralised monitoring and control within areas such as manufacturing, the need to support mobile workers in performing diagnosis and repair task still exists and is in fact increased. Thus as some tasks have become more centralised with workers no longer permanently stationed near the machines for which they are responsible, other workers remain mobile, dealing with the tasks where physical presence is needed but without the support of dedicated operators for those particular machines.

These mobile workers must be provided with appropriate information resources to allow them to carry out their activities. The nature and amounts of information required are a major driver for the design of decision support systems. When large volumes of data are to be displayed, graphical displays are an obvious choice, due to the perceptual properties of well designed displays, making search, comparison and certain forms of reasoning easier to perform [1,7]. Furthermore, different external representations of information can have a fundamental effect on what relationships are perceivable, and can act to co-ordinate and control collaborative tasks [3].

With large volumes of data, we encounter specific problems, particularly the keyhole effect of the user becoming lost within a large "virtual perceptual field" of the information which can possibly be displayed [6]. With small, mobile devices with diminutive screens, there is a further motivation for the use of graphical displays, as the very low information densities possible with text are a major barrier. These small displays may also aggravate "keyhole" problems. For navigating complex information spaces, using multiple interrelated views is a standard technique, however it is hard to have multiple simultaneous views on a small display. There is a further difficulty in that dedicating a lot of space to navigation will further reduce the amount of data which can be displayed. This motivates the integration of navigation and content, to achieve greater economy of space, but these associations must make sense in terms of the conceptual relationships present in the problem domain, and preferably also the normal flow of work.

In this paper we will examine display design strategies for complex, hierarchical information structures involved in decision support. Our particular focus is on supporting mobile workers using context aware information systems.

2. DESIGN SPACE FOR DECISION SUPPORT SYSTEMS

In this section we look at the design space for decision support systems within an industrial setting. To consider the information needs of the mobile worker we can see a dependency on the location of the worker, the possible actions at that location, and the information resources needed to perform these actions. We take the premise that there will often be a strong association between a physical location, and the possible actions at that location. This generates an association between the information needed to resource that action, and the location. This dependence on location makes the physical organisation of the environment important, as we can expect tasks to exhibit locality in space, i.e. we are more likely to access information on nearby related components, as there is a cost associated with movement. However, while it is reasonable to expect that there will be related components within a given location, there may also be related components in different locations. Thus location information will in itself be relevant to the users decisions and planning. Another aspect is the task context, which will manifest itself in terms of the history of information access (i.e. locality in time), as we are likely to have recently accessed information relevant to our current tasks and goals. Let us briefly consider the ways in which the system might be controlled in terms of these concepts

Central control. One option, common for supervisory control, is to have a single fixed control unit, or control room. In this case we often have a representation of the physical or functional organisation of the system, which is used for navigation to the appropriate information concerning the controlled components. There may be several dedicated displays associated with particular areas, effectively using physical (visual) navigation instead of navigation through the system. As commented on above, for real applications centralised control must go hand in hand with more mobile workers for tasks such as diagnosis and repair, so this is not a standalone strategy. The design of such a control-room interface could be dealt with through the combination of CWA & EID.

Distributed control. Another possibility is to have workers close to the components being controlled, in which case we require many local system control units. There is no navigation to information relevant to the location, and hence no representation of the physical or functional organisation of the system. Task context and history are not always available where different people may be using the control units to perform different tasks, although solutions are possible with the overhead of user authentication (which may be addressed via context awareness technology for user identification). Here a smaller partial view of the system may be sufficient to support the task.

Non context-aware mobile control. Where we have control via a mobile device which is not context aware, we must navigate to the information relevant to our particular location, and hence have location represented in the display. This is likely to be awkward and time consuming on a small device. Such devices are generally personal rather than shared, so history information for a particular worker is available and hence task relevant context can be taken into account.

Context aware mobile control. In this case, navigation to information relevant to our location need not be explicit. As with the configuration above, history information and hence task relevant context are available. Interestingly, we can see a similarity between context aware distributed control and context aware mobile control configurations, as both support personal task context and location awareness, but there may be compelling reasons why large scale ubiquitous displays are not desirable (cost, weight, access, failure and maintenance, power consumption, security, contention etc.). We concentrate on the mobile context aware scenario in this paper.

2.1 ADS for information structuring and navigation

A major advantage to the CWA approach is the ability to provide a structure for the information space, which is both common across all applications, increasing consistency, but which can also serve as a mechanism for navigation through a "whole-system" interface. This is achieved through developing a number of hierarchical representations of the system - the abstraction decomposition space (ADS) [4]. These hierarchies include functional and physical decompositions. The aim in designing an interface around this concept is to support reasoning about the function of the system at different levels of abstraction.

In extremely large systems the levels of the ADS used to structure information may match the organisational structure as roles at higher levels of the organisation are often concerned with goals and information at higher levels of abstraction within the system. In an industrial setting for example, we might see a rough correspondence between the manager, supervisor and operator roles, and system, subsystem and component levels. However, even if this is the case, there is often a need to step back to a higher level of abstraction or drill down to different level from that which is the main focus of a particular role.

One motivation for a whole-system view is where variety and complexity of roles and sheer scale of information means generating large numbers of very task specific interfaces may not be feasible, and even so users may sometimes need to make excursions into areas of the system beyond their responsibility to check for knock-on effects of local decisions. While navigation within the system may or may not be presented to the user in the same terms as the ADS, it provides a useful reference and underlying structure for such navigation.

2.2 Removal of explicit navigation in context aware systems

The basic premise of context aware decision support systems is that they remove the need for explicit navigation through the information space, as information relevant to the context (location) is displayed. For example, when a mobile worker approaches a particular tool (machine), information and controls for that tool might be displayed.

However, in terms of a decision support system design which is based on CWA, we can see the removal of this explicit navigation as lessening awareness of relationships between a particular low-level component and its peers within the different relevant abstraction hierarchies. Thus, even if the possibility for navigation is still present, a form of awareness at the user level has been lost. A simple example of such awareness would be where the user navigates to a particular component via the hierarchy; they know the position in hierarchy as they have passed through the parent nodes of the component, and they will also know the peers of the component. This could be physical (nodes in same physical location) or functional (nodes with the same purpose and capabilities).

Thus, automated (context aware) navigation removes the explicit representation of the structuring of information in terms of the ADS, and the relationship of information at a particular level in the hierarchy to information above, below and at the same level. The situation is further complicated when we consider relationships across several hierarchies (a refinement of the method we have found necessary to deal with realistic levels of complexity). A question then arises as to whether we can systematically re-introduce this "relationship awareness" to our design by other means.

3. IDENTIFYING INFORMATION NEEDS

We can see the design of decision support as having two major stages - deciding what are the information needs of the user, and secondly how this information should be presented to the user (considered in section 4 below). The CWA approach generates a set of hierarchies for structuring the information space, but the designer must also consider the information needs of the mobile worker within this information space. In previous work [under review] we have considered the mapping of use cases in the form of a decision ladder onto the abstraction hierarchy as a means of understanding how the information needs change while carrying out the use case, and how this may be used to inform design of support for the navigation. This can also be applied to the design of mobile displays, but we must ask what may be different for the mobile case. Stepping through levels of abstraction as we traverse the decision ladder does not seem to be directly affected (a recommendation would be that this should be the most obviously afforded navigation). The reduced amount of data that can be displayed per screen will mean more transitions between screens are likely to be needed, and so if we are designing a display to support a particular use case, these transitions should synchronise with transitions on the decision ladder where possible.

Another family of approaches which may throw light on information needs in this context are allocation of function techniques. These are concerned with deciding which functions to automate or partially automate. For functions which may be partially automated we can produce an IDA-S template [2] to characterise the use of information. This analysis has a direct bearing on display design. Consider *information integration*: this is a specific type of perceptual and cognitive task, for which certain types of analysis (consistency of the representations, amount of searching, complexity of comparisons) are appropriate; it can be supported directly in the display through careful consideration of the perceptual properties of the information representation. *Information collection* is partially helped by displaying information relevant to the task context and current possible actions. *Decision evaluation* generates information needs, which may be thought of in terms of the task context and ADH.

Thus, while we may view the design problem under investigation as having two stages (information needs and information representation), the analysis of needs can shed light on the most appropriate representations, either through looking at the structuring of the system (and hence information about the system), as in the ADS, or through analysis of actions and the use of information (as in IDA-S).

4. DESIGNING FOR RELATIONSHIP AWARENESS.

The area of display design is complex in itself, with many factors to take into account and no overall methodology for the many different types of analysis that are possible. For the purposes of this discussion, we will restrict ourselves to the mobile decision support scenario introduced earlier. The form factor itself introduces a number of constraints, reducing the design space and making some of the display design tradeoffs more extreme.

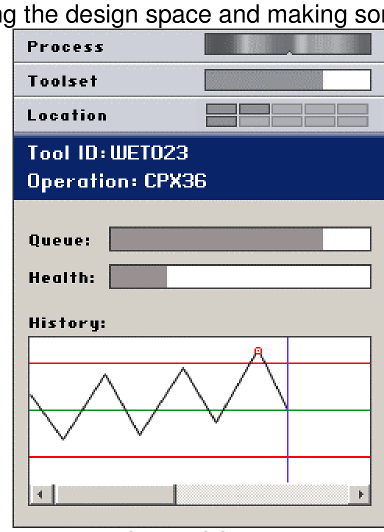

FIG. 1 - TOOL

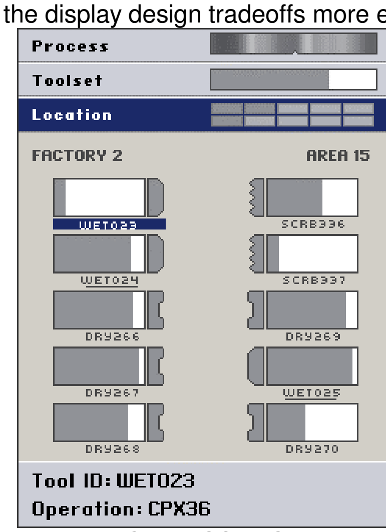

FIG. 2 - LOCATION

With the mobile, location aware scenario, the major difference from an interaction point of view is that there is no explicit navigation (through a representation of the physical hierarchy or otherwise), to information relevant to the tasks which the worker can perform in their current location. This saves time and effort, but may result in a loss of awareness of relationships between information, and subsequent strategies for finding other relevant information within the system (this can be seen as a form of situational awareness).

However, we can use the parallel ADH abstractions to break down the possibilities for encoding these relationships in the display. Consider as an example an industrial control scenario where tool specific information is supplied when in the proximity of that tool (Fig.1). From an analysis of the possible use cases, we identify three likely transitions within the ADS, along the physical, functional and process hierarchies. It is straightforward to provide a means to navigate to this information, but it would be better to contextualise the information being viewed on a more continuous basis, supporting awareness of the position of the information being viewed within the ADS. One approach suggested by the analysis would be to use summary information about the peers of the node being viewed within the different hierarchies, as illustrated for the physical, functional and process views in figures 2, 3, and 4. Hence, although embodied navigation means that there is no longer a strict requirement for representation of the physical ADS on the device for navigation purposes, we can convey the relationships between information in a way that is consistent with the ADS.

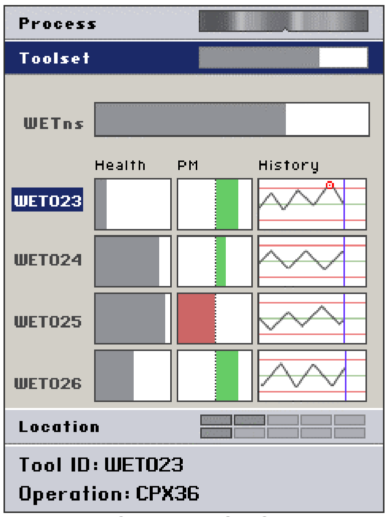

FIG. 3 - FUNCTIONAL

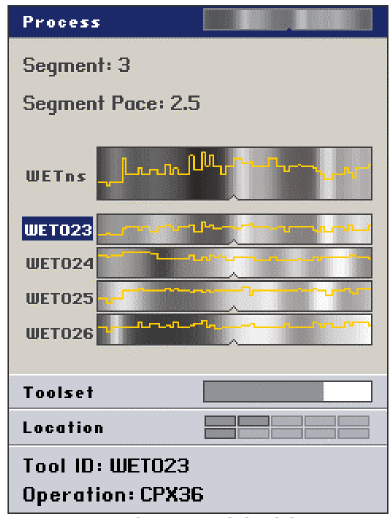

FIG. 4 - PROCESS

For example, consider the case where we have recently been looking at components that are close together, we may wish to indicate their relationship within the functional hierarchy (summary data for toolset, with a transition to fig. 3). Alternatively, we may be viewing information on components which are related within the task context, and it would be appropriate to indicate that they are close together (summary data for location, with a transition to fig. 2).

5. CONCLUSIONS

There is a need for a methodology for display design, taking into account particular constraints of mobile devices. In this paper we have focussed on a small number of problems relating to the design of mobile decision support systems. We view the problem in terms of identifying information needs, and mapping information needs and characteristics of use onto display designs. The task of identifying information needs can be quite domain specific. For the particular example of decision support systems, techniques such as cognitive work analysis may be appropriate. By contrast, much of the work on display design is generic to graphical representations of information, although there will be particular types of information display which are complex and distinct enough to require independent study and guidelines. We have identified a specific issue to do with a loss of awareness of relationships between information, which comes with the use of location aware decision support, and looked at how this may be addressed at the display design level.

ACKNOWLEDGEMENTS

Connor Upton is supported by an Intel Ireland Postgraduate Research Scholarship.

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