

CONFIGURABILITY AND DYNAMIC AUGMENTATION OF TECHNOLOGY RICH ENVIRONMENTS

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ABSTRACT

The notion of usability has developed since the beginning of the HCI-field from human factors to a concept highly relative to specific use situations and including social aspects concerning communication and collaboration. What comprises usability in concepts based on augmentation technologies? Based on experiences from interaction design in technology rich environments we argue that the concept of augmentation may facilitate a shift in focus within the HCI community away from standardized interface formats and towards a new and diverse world of distributed and dynamic interaction design where the possibilities of configuring interaction for a specific use situation is an important aspect of usability.

1. INTRODUCTION

As the design materials of HCI develop towards ubiquitous computing, the range of potential users and use contexts is rapidly expanding and traditional approaches to interaction design are called into question. In the light of these changes augmentation is in several ways an interesting perspective on computer support. As opposed to the ideas of using computers to automate tasks, the notion of augmentation stress that information technology can be designed for enhancing both the human sensing of the environment and the human capability of intervening in this environment. Similarly augmentation seems to offer a way of avoiding the widespread common-sense duality of the physical and the virtual. Augmented reality (AR) technologies were for long associated with a fairly limited range of human interfaces such as head-mounted displays through which the user could experience visual overlays to the visual appearance of the surroundings. The origin of the representations displayed has in general either been generated offline (as in museum type systems) or they have been the result of complex vision techniques applied to an on-line recorded video image. From a usability or human-centered design perspective these interpretations of augmentation appear to be far too modest and single minded.

2. AUGMENTATION IN PROCESS CONTROL ENVIRONMENTS

The interest in ubiquitous computing beginning with Weiser (Weiser 1991) has mainly been fueled by application examples from environments with a fairly poor penetration of technology such as office or home environments. The attempts to let the human-computer interface transcend established formats of screens and keyboards have been governed by the need particularly in collaborative settings to make information technology blend into the mixed media environments of social interaction (Ishii and Ulmer 1997). While we share this search for new interaction modalities we have found it particularly interesting to study technology-rich environments in which all human activities are highly mediated by technology. The process industry provides an interesting example. The work settings of the process industry are both rich and mature in terms of technology density and represent a very thoroughly constructed setting. In addition the process plant has produced one of the strongest guiding images for the duality between information and actual process: the control room. In later years the focus in the industry has been shifting from well-known automation trends towards a more delicate interest in the interplay between technology and people (Zuboff 1988). To look into interface design for such an environment from the perspective of augmentation along the lines suggested by i.e. Welner et al. (Welner et. al. 1993) invites augmenting the sensing and intervention capabilities of process operators in ways which we believe raise challenging questions as to what, where and how to augment an already highly constructed environment.

2.1 TOWARDS DISTRIBUTED PROCESS CONTROL

In collaboration with process operators at a number of process plants we have worked with the design of mobile interfaces for process control systems. We sought to challenge the strong guiding image of the centralized control room searching for more flexible means for supporting process control work through augmentation. At some plants steps have already been taken towards more distributed process control as PCs in the offices of process operators, and at strategic places in the plant, have substituted the centralized control room. The large geographic area often covered by the plants, further accentuated the tension between centralized control facilities and local needs of access to process information in daily operator work. Ethnographically inspired studies of process control work revealed some characteristics of this tension in the daily work practice.

The importance of physical inspection

Operators spend considerable time making inspection rounds in the plant. During these rounds they can verify the mapping between digital representations of machine components and the physical state of the same components. Discrepancies between readings and actual states are a common source of problems in process control and operators in general learn not to rely on information provided from only one source. Physical inspection allows operators to collect visual, haptic and auditory information not provided by the control system and they are equally attentive to the operation of components as to the quality of processed materials. Presence in the plant is not just a matter of collecting information but also helps operators to establish and maintain a shared understanding of the process. Finally, operators learn about ongoing work from interpreting traces of their colleagues' activities (e.g. tools left for later use or dismantled components) and as they occasionally »bump in« to one another during these rounds they exchange information on current problems. A large part of the work co-ordination is done informally in spontaneous meetings on various locations in the plant.

Dynamics in process control

The general interaction scheme implied by traditional process control systems suppose operators to monitor the system for alarms and, as they appear, take appropriate action in order to bring the system back to the desired state. However, this stands in contrast to research on process operator work practice (e.g. Zuboff 1988) and also to the results from our field study. We found that many alarms are caused by well-known and unproblematic events that do not call for action. Rather, physical inspection allows operators to discover problems before they generate alarms in the system and in general the work strategy of operators is highly proactive. This also reflects the dynamics of process control. The plant is never in any simple sense just up and running. Continuous variations in process input, combined with on-going construction and repair work disrupting normal routines, means that new problem settings constantly evolve. Problems that arise often have consequences further along the production chain calling for collaborative efforts in problem solving. As these situations are approached the exact nature and location of the problem is often not clear. Operators frequently engage in setting up small-scale experiments as a strategy to frame the problem or to test a tentative solution. This may involve the use of temporary instrumentation where readings cannot be provided from the control system. Results from experiments can lead to new experiments and problem solving often evolves as a dialogue with the situation at hand.



Fig. 1. Inspection allows operators to collect information not provided by the control system.

2.2 DISTRIBUTED CONTROL AND AUGMENTATION

The importance of physical presence in the plant together with the proactive work strategies demanded by the dynamics of process control point towards a need for a process control system structure that is distributed rather than centralized. Also, the operators' experimental approach to problem solving requires a highly flexible support where monitoring can be set up based on the nature of the problem. In our view this is a context for human machine interaction where augmentation seems to be a particularly interesting approach allowing access to process information from the control system to naturally »blend in« with the operators interaction with physical machinery. Moving towards distributed control raises at least two issues: the density of access points and the requirements for interaction at these access points.

The density of access points

Placing PCs at strategic places in one plant studied was a step towards more distributed process control but the density of access points was clearly not enough. Operators were frequently forced to switch between interacting with the machine components of the plant and interacting with digital representations of these same components at the nearest PC which disrupted their workflow. Also, the PCs provided the same fixed view of the process as the centralized control system and did not support adaptation of the interface to the problem at hand. The goal of augmented reality systems, as described in most current research, is to enhance the users' view of the real-world by providing context-based information using a mobile device. Ubiquitous access to process information through an AR-system could provide operators with »maximized« density of access points and process information available anywhere in the plant. However, AR-systems are often based on the notion of overlaying the real world with digital information. Such »context-sensitive browsing« of a statically augmented environment does not respond to the process operators need for configuring interaction for the specific problem at hand.

Requirements for interaction – creating and sharing temporary focal sets

The operators' need for flexible access to process information and the issue of distributed control is not simply a dichotomy between *either* centralized control *or* local control facilities in the vicinity of physical inspection points at a particular place in the plant. An operation problem in process control seems only rarely to be localized to a particular geographical location. It is more often related to the malfunction of a combination of components in different parts of the plant, which in a non-trivial way has to be »brought together« at the operators »place of action«. The spatial positioning of these components may be far apart creating a need for remote monitoring. Second, operation problems in process control are dynamic. The set of machine components that needs to be monitored evolve out of the problem situation at hand and reflects the particular perspective on the problem constructed by operators. The components involved in a problem may be described as a set of »focal points« constituting a view of the production system where certain parts of machinery are temporarily connected through a set of casual relationships constructed in a problem framing activity by the operators. We use the term »temporary focal set« to describe a set of focal points associated with a particular problem. The temporary perspective that the focal set represents may change as the operators collect more information about the problem. The established »temporary focal set« is maintained and monitored until the problem is solved. Thus, a core ingredient in operator work at the plant is a constant movement between different temporary focal sets, often set up in parallel, based on evolving potential problem situations that become established, are maintained and then dissolve.

2.3 CONFIGURING TEMPORARY FOCAL SETS

Based on the results from our field studies we entered into a close collaboration with process operators in designing a handheld device for more dynamic process control. The resulting device – the »Personal bucket organizer« or »Pucketizer« (Nilsson et al., 2000) – supports configuration, monitoring and maintenance of temporary focal sets. The Pucketizer provides three functions, which can all be seen as temporary augmentations of the environment providing the operator with an individual view of process information. With the device the operator can establish links to components as he is confronted with them in the plant and lets him organize these into temporary focal sets. This has similarities to the »pick-and drop« functionality suggested by Rekimoto (Rekimoto 1997). The device also facilitates simple monitoring of process information and setting of temporary alarms. Finally the device enables the operator to annotate the environment by leaving audio »notes« on the spot linked to a particular component. Basically the interface concept is an attempt to deal with the same problem of bridging the physical and the virtual world as discussed by Want et al. (Want et al. 1999). However, acknowledging the richness of representations in the process plant we suggest going beyond the duality of digital vs. physical. Rather than distinguishing between representations of plant data in different media we prefer to see the process plant as one large

mixed-media interface where operators are dynamically setting up and exploiting augmentations derived from the problem at hand. What we learned from designing for this kind of dynamic augmentation was that there is not in operator terms any fixed spatial organization of the work space to augment, but rather a constantly changing set of spatially floating relations that has to be monitored and evaluated. Furthermore it became clear that establishing a particular view of the process through configuring »the interface«, and exploiting this view to solve operational problems are so closely intertwined that »configuration« can not be meaningfully separated from »use«.

3. STAGING FUTURE AUGMENTED ENVIRONMENTS

The dynamics of process control, where the operators approach to solving a problem evolves as an outcome of a proactive problem framing process rather than as a response to alarms generated by the process control system, is an important aspect of use that in our view has earlier been neglected in designing technology support for this work domain. In designing for this context a user-centered design process with a high degree of user participation therefore seemed a natural starting point. In order for user participation to be successful representations of design ideas are needed that allow users to engage in a dialogue with the designers and the materials of the design situation (Greenbaum & Kyng, 1991). Furthermore, in exploring concepts that transcend traditional formats of human-computer interaction it could be argued that there is a possible tension between the need for visualizing concepts for users early in the process and the amount of resources needed to produce vivid prototypes of augmentation technology. Rapid prototyping of such concepts is difficult to achieve with the tools available, possibly indicating less opportunity for users to participate in the design of augmented environments. The high contingency of process control work leaves the interaction designer with no solid ground for producing use cases to drive conceptual development or prototype testing. As a group we have earlier worked with ethnographic video as a kind of design material in which we capture prototypical work situations that prompts our design work (Binder, 1999). In designing the Pucketizer we expanded this approach by inviting process operators to script possible work scenarios. The scripting was typically made in the plant and in front of a video camera, in order to explore and maintain possible ways of using new devices. An important part of constructing such potential use scenarios is the use of simple mock-ups, as placeholders for new technology and introduced as props in staging future work situations (Brandt and Grunnet 2000). Figure 2 shows a process operator, in dialogue with a member of the design team, using his everyday environment to spur envisionment when confronted with simple mock ups of a new design. In our perspective, adapting techniques for low fidelity prototyping to information technology as a rapidly developing design material seems a promising approach in designing for highly contingent use situations.



Fig. 2. Augmentation provides a good starting point for envisioning new work practices.

4. DESIGNING FOR DYNAMIC AUGMENTATION – CONFIGURING INTERACTIVE SPACES

In our studies the clear mismatch between established interaction design schemes of process control systems, implying an alarm-driven work mode, and the highly proactive work practice of process operators provides a strong argument for pursuing an augmentation perspective in future interface design. The challenge facing us in pursuit of augmentation is however the constant change characterizing such environments as process control. There is no normal state but rather process control work involves constantly shifting between different parallel temporary focal sets constructed from current problems. The spatial distribution of focal points may be large requiring remote monitoring and as problems in one part of a plant often have consequences further down the production chain problem solving often involves coordinating work. In addition to process information from the control system

visual, auditory and haptic information from different positions in the plant is often needed. Based on the above we argue that in technology rich and highly constructed environments, using process control work as an example, there is no privileged or »best« spatial position for problem solving and collaboration in process control. The dynamic aspects of problem solving, where experiments are an important part of the problem framing process, create a need for letting the user configure the interaction with the process control system based on the contingencies of the current problem. Therefore, in our view there is no privileged or »best« view of the process.

Beyond process plants

Löwgren (Löwgren 1995) identifies five perspectives on usability that has developed in the HCI-field and still coexist in parallel: general theories for predicting usability based on human factors research; usability engineering relating usability to a specific system and tasks; subjectivity proposing usability as a property of specific use situations; flexibility proposing usability as a property of long term use with continuous adaptation to changing needs; and a slightly more vague perspective of sociality accounting for social aspects of use as collaboration with roots in the CSCW-field. In developing concepts for augmented environments in process control, flexibility and continuous adaptation to specific use situations seem to be the most important aspect of usability. Augmentation however can provide the interesting possibility of designing for configuring interaction for the situation at hand. This will sensitize interaction designers to respond to the dynamic needs of a particular practice rather than searching for general interaction schemes fixing functionality towards an only slowly evolving system of tasks. We would like to stress *configurability* of an augmented environment as an important aspect of quality in use. This can be achieved not through designing generic tools for controlling fixed functionality but through designing supportive interaction technology based on a deep understanding of various practice situations staged in a specific context (Binder 2001). The high contingency of everyday use situations, with no guiding regular use cases, stresses the need for a high degree of user involvement and design representations that support a constructive dialogue between users and designers. In our experience low fidelity mock-ups with little or no functionality inscribed can successfully be used as »props« to »stage« future use situations together with users as a basis for design. This provides possibilities for both grounding design in work practice and stimulating transcendence from existing work conditions to future technological possibilities.

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