Augmenting reality in mobile substrates

On the design of computer support for process control

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Abstract

The paper investigates augmented reality as a perspective on the design of computer support for process control in a distributed environment. Based on empirical studies of work in a wastewater treatment plant, three technical approaches on augmented reality — augmenting the user; the object of work; and the environment — are examined in terms of a collection of design scenarios .We conclude that these approaches when used as metaphors rather than a consistent theoretical framework, may inform design of mobile support for process control work.

Keywords: Augmented reality, process control, mobile computing, human-computer interaction, participatory design, workplace studies.

BRT Keywords: AB, FA, FC, GA, HD

Introduction

Advanced technical (process) settings, such as modern wastewater treatment plants, are characterised by being highly distributed and dynamic. A possible strategy for supporting work in such settings is through the introduction of mobile technology. In this paper, we look at how and to what degree an augmented reality approach may inform design and, as such, bridge the gab between the dynamic, distributed technical setting and the implementation of computer support in mobile substrates.

Process control as an engineering discipline includes areas such as automation theory and cognitive systems engineering. In the former, the focus is the integration of components at a systems level, an automation level and a field level (Black, 1991), whereas in the latter, the focus is errors and other hazards in the control rooms of, for example, nuclear power plants (Rasmussen 1986, Reason 1990). In the field of CSCW studies of similar process control settings have also been done, such as the studies from the London Underground (Heath & Luff 1992) and air traffic control (Hughes 1995), and here the emphasis is on the collaborative aspects of risk management.

Mobile technology is particularly well-suited for a distributed work environment, because mobility supports distribution rather than delimits it, which is the case for much of the existing information technology. Acknowledgement of the significance of mobility and the use mobile devices in distributed collaborative settings has increased over the years, which is reflected in the work of Kristoffersen & Ljungberg (1997, 1998), Luff &

Heath (1998) and Myers et al. (1998). Furthermore, Dix et al (1998) argues that the interplay between the real and the virtual is at the core of the design of co-operative mobile applications because of the shared virtual and real nature of both user and artefact.

The concept of virtual reality has attracted much attention since the invention of the DataGlove and head-mounted displays, yet it is still to be proven practically applicable. Concepts of mixed, or augmented, reality have been launched as strategies for integrating the virtual with the real world (Benford et al. in press, Wellner et al. 1993).

Based on a previous study of the dynamics of work in a wastewater treatment plant (Bertelsen & Nielsen 1999), the use of mobile technology to support work in this environment seems very promising. Using real work scenarios from the study, described in more detail below, we investigate how the three basic approaches to augmented reality (Mackay 1998) - augmenting the user; the object; and the environment - may be used to inform design of a mobile device to support work in a wastewater treatment setting and discuss the problems in introducing a separation based on interaction when relating them to real work situations. We show that it is the use rather than the perspective that controls the design of the mobile artefact, but that the augmented reality approaches may indeed inform design by shedding light on situations from three different angles.

The following section describes the wastewater treatment plant, we visited as well as its operation, and sets the scope for our case study. We then look at augmented reality as an approach for informing design. In the following section we relate the three basic augmentation techniques to real work scenarios, creating future scenarios. We then regard how a mobile device may be constructed to support work at a wastewater treatment plant by relating it to all three augmentation approaches, with inspiration from the future scenarios. With this, we evaluate the use of augmented reality in relation to design of mobile substrates for wastewater treatment.

Wastewater Treatment

The case study is part of a long-term research cooperation in the areas of HCI and CSCW involving Danfoss (a large scale Danish mecatronics manufacturing company) and the Computer Science Department at Aarhus University as well as several other partners. The purpose is to explore the theoretical notion and practical design of common information spaces. The project has focussed on field studies of three wastewater plants, conducted by researchers from the participating organisations. This paper reports on our observations of work at one of the plants. We selected 6 days, within a 5-month period, to follow workers through their entire daily routine. Different researchers followed different workers, using hand-held video cameras to capture the events. We later analysed the video, with special emphasis on the daily work practice, use of artefacts, and how workers dealt with the disruptions. We selected groups of clips to present to the plant employees during feedback sessions and user workshops. We also compared the work practices at this site with data collected by other project researchers at the other wastewater treatment plants.

The wastewater treatment plant

We conducted a study of a modern wastewater treatment plant in Denmark, paying particular attention to how formalisation and flexibility exist in the work practices, and how it affects the coordination of work. The purification process at the plant includes mechanical, chemical and biological phases. The resulting segmented sludge is used to produce gas, which produces enough electricity to run the plant. The remainder is pressed and taken away to an incinerator plant. The plant was one of the first to implement automatic process optimisation for the removal of nitrogen. The automation has been possible due to the development of new sensor technology, which allow for on-line measuring and control of the primary parameters of operation. Not surprisingly, the process optimisation has radically decreased the use of chemicals. The plant has an estimated capacity of 220.000 person equivalents. However, it is constantly running at 110 - 150% because the plant has not been able to expand to match the increase in the city's production of wastewater.

The work

The wastewater treatment plant employs a total of 8 people. The two managers are responsible for the overall management of the plant. The remaining six employees work in pairs, with the following areas of responsibility:

- chemical test lab, receiving the sludge-trucks, preliminary sorting area, sand trap
- outside plant areas, putrefaction tanks, sludge tanks, gas-turbine building, control room
- sludge press

The three pairs of workers are each responsible for tasks associated with a specific part of the treatment process. Individual workers may temporarily take on other tasks, as when someone is ill, but the overall division of labour is quite stable. Within the bounds of the set of work tasks, individuals are free to 'juggle' the tasks as the situation demands. An important goal of this organisation of the work is to keep the relevant part of the plant in a condition that will allow the underlying purification process to run effectively, even when the worker responsible is home on nights or weekends. For example, the worker in charge of the lab spends two to three hours every morning collecting water samples and sludge and then analysing the quality of the water at different stages of the purification process. The worker in charge of the gas turbine area checks each of the different machines and collects the read-outs of how much gas has been produced during the last 24 hours. The plant manager's area of responsibility is wider, but the tasks are of the same nature. He starts every morning at his computer, getting an overview of the status of the plant by looking at his customised graphs and the lists of alarms.

Although each worker's daily routine of checking and maintenance is highly standardised, we also find a high degree of unpredictability at the plant. The majority of alarms received at the wastewater treatment plant are warnings, such as when the water level is at the maximum limit for a tank. Some alarms call for (relatively) immediate action, while others may be addressed over a period of days. Sometimes the worker can handle it himself, other times an outside specialist must be called. If the alarm is due to machine failure, several workers may completely break off their daily routine and enter into a cooperative problem-solving effort. Workers and managers specifically pay attention to warning alarms and physical signs of problems, since it is much more desirable to prevent rather than recover from machine breakdowns.

The wastewater plant is continuously engaged in a number of experiments to optimise the purification process, to produce cleaner water and decrease costs. Experimentation usually involves introducing new technology or work practices that may provoke unanticipated events and effects on everyday work. Outside visitors, such as school classes, also disrupt the normal routine, even though the visits are carefully planned and executed.

In general, the daily work routine has a dynamic structure. The workers need a deep understanding of the assignments and the plant itself in order to perform their tasks without continuously having to reinvent their work practices. This enables them to place equipment in the area for later use, and allows them to redefine the order of tasks in order to cope with the numerous events that cannot possibly be anticipated.

As an aid for exploring this environment to better understand it and design mobile support, we have chosen the augmented reality perspective. We see important connections between the physical and the virtual within the work at the wastewater treatment plant, that is the information given by the physical layout and the individual components of the plant, and the information within the computer system. The augmented reality approach supports making such connections more visible and using them as basis for design.

Augmented reality

Augmented reality is an approach to information systems design focusing on redirecting information back into " the real world" by augmenting existing objects instead of replacing or representing them by purely computer based systems. The argument is that non-computer based artefacts in the workplace often mediate work in subtle ways that are impossible to transfer to new computer based artefacts; paper flight strips in air traffic control being one of the well documented examples (Mackay et al. 1998). Augmented reality is an alternative approach to virtual environments. Mackay (1998) describes three technical approaches to design of augmented reality, spanning a continuum of technical substrates for mixed environments: augmenting the user; physical object; and the environment.

When augmenting the user, the user is enhanced with respect to perception and action by wearing or carrying devices. Head mounted transparent displays and data gloves are obvious examples. (Wrist watches, binoculars, and gloves can be seen as traditional non-computer based augmentation of the user).

When augmenting the object, input and output of computational devices are embedded into physical objects. White boards recording what is written on them and LEGO bricks with embedded computational power are examples of this. Augmenting objects is tightly related to "ubiquitous computing" (Weiser 1991), that is, the idea that computing in the future will be embedded in any everyday object.

Augmenting the environment is done with independent devices, by way of which information is collected from objects or user action, or displayed onto physical objects. Augmenting the environment can be understood as indirect input and output.

To some extent this classification points to a progression from naive brute force use of VR gear to less intrusive approaches.

Augment	Approach	Technology	Application
User	Wear devices on the body	VR helmets Goggles Data gloves	Medicine, Field service, Presentations
Physical Object	Embed devices in objects	Intelligent bricks, Sensors, receptors, GPS, electronic paper	Education, office facilities, Positioning
Environment surrounding objects and users	Project images and record remotely	Video cameras, Scanners, Graphics tablets, Bar code readers, Video projectors.	Office work, Film-making, Construction, Architecture

Table 1. Examples of augmented reality approaches, with relevant technologies and applications (adopted from Mackay 1998).

Augmentation as design strategy

From a work-oriented perspective, we distinguish between the acting subject, the object of work, and the artefacts mediating the human activity to achieve the outcome. In this terminology augmented reality is realised through redesign of mediating artefacts. The above three categories of augmentation point to specific types of mediation, but not in a very consistent manner with respect to a work oriented perspective. Augmentations can be seen as a general attitude in design, acknowledging the historical development of work and the crystallisation (Bærentsen 1989) of work with one generation of an artefact into the next generation of the artefact. Augmented reality as a general design strategy is closely related to the idea that design of computer artefacts should be accomplished as a transformation of artefacts from the domain of work (Bertelsen 1996).

Selected situations from our field study

Based on our work with the empirical material we have selected two situations which are suitable both for understanding wastewater treatment work in general, and to explore the concept of augmentation in mobile substrates specifically.

The water is brown

As part of his daily round, Bob is checking the area around the sludge tanks and notices that the surface water in the tanks is brownish. He immediately proceeded to the building the water would have come from to check a filter he suspected to be the cause of the discoloration, and that turned out to be in dire need of a rinse. He explained that if the water hadn't been discoloured, he would have gone down to check the filter anyway because that building is part of his area of responsibility, but that he would not have done so until much later.

This situation may seem too simple to be of interest; one man works alone, going on a well-defined round. However, even though the part of the plant associated with the tasks on the round, both physically and process-wise, and the goals (namely, checking up on a number of things on the plant) are well-defined, we see that this situation reveals some interesting points with regards to the identification of modes of formalisation and the process.

Because he encounters the brown water, which we may call a causal process outside of, but interfering with his actual work, his goal changes with regards to what needs to be done when, and he initiates a change in his routine. Even though the daily round is well defined in terms of which tasks should be done and checkpoints visited, the routine still leaves plenty of flexibility for the reorganisation of the order of tasks. The alternative, which would be to perform the related tasks in a strict sequence, perhaps related to the physical layout of the plant would contradict an overall motive of work at the plant, namely, to keep the purification process running continuously. The lack of response to warnings such as the brown water would seriously increase the risk of an actual machine breakdown. Going exclusively by the physical layout also renders the process-look at the purification process invalid, because it becomes impossible to look at connections between the components that are related in the process but not physically standing side by side. Most importantly, though, is that these reservations hold more so for cooperative situations. Because the workers have to leave their routines to recover collectively from a machinery breakdown, flexibility is even more crucial.

After arguing that a high degree of flexibility is important in the everyday routines, we would like to emphasise that this is not the case for all aspects of wastewater treatment processes. It would be absurd to claim that flexibility is necessary in the physical flow of the water through the plant, thereby making it possible to send the water out into the bay before the chemical or mechanical cleaning process. This is also why we argue that the technical structure of the wastewater treatment process needs to be identified and juxtaposed with the continuously changing processes.

Making tests

7:00 a.m. – Joe goes down to the lab to clean the containers used for yesterday's lab samples and starts his daily tour across the plant. He picks up two of four containers and walks out into the plant to collects samples of the water from the inlet and the secondary setting reservoir. He exchanges the empty containers with the ones that have been gathering samples taken automatically every 5 minutes during the past 24 hours. Returning to the lab with the samples, he picks up the remaining two containers and goes on another 'round' to pick up samples from the post setting reservoir and the biological sludge. In the building with the automatic sampler for the post setting reservoir, Joe meets a colleague and asks him if he knows where he can find some more paper for the matrix printer in the lab. He suggests that Joe call the foreman, who will know for sure where to find it, but Joe decides to take a look around the control room before contacting The foreman – Joe thinks the foreman is quite busy this time of day. He doesn't find the paper in the control room, so after completing his round of collecting samples, he walks up to the meeting room and finds some printer paper in the utility room. In its entirety, the gathering process has taken 15 to 20 minutes.

Another colleague, who works in the building next to the lab, calls Joe over to tell him that the contents of the primary clarifier looks strange today, almost as grey as cement. They briefly discuss what could cause this and decide that the best cause of immediate action is for Joe to pay extra attention to the lab results today.

Joe goes into the lab to start his analysis of the wastewater samples. He has to analyse the water for nitrate, phosphor, ammonium, organic matter and the total amount of dry matter. Most of these tests take 10 minutes to finish. At the 9 a.m. coffee break, only the tests that need special heating remain. These (analysis of organic matter, total-phosphor, total-nitrate and total amount of dry matter) require about 1 1/2 hours in the oven or the curette-heater. After the coffee break, Joe finishes the last tests and joins his colleague in the computer room next door – none of the analysis results proved out of the ordinary despite the strange-looking grit so they agree there is no need to do anything out of the ordinary.

AR scenarios

To explore the three technical augmentation strategies as metaphors in the design of computer support for wastewater treatment work, each of the situations described above are rephrased in a scenarios augmenting the user, the object and the environment, respectively.

The water is brown – augmented scenarios

The first set of scenarios, based on the "the water was brown" situation, can be seen as material crystallisation of Bob's internalised interpretation of the water in sludge tank in the situation of his daily inspection round.

Augmenting the user

As part of his daily round, Bob is checking the area around the sludge tanks and notices that the surface water in the tanks is brownish. He puts on his VR glasses to look at the water. The glasses project system information onto the lenses. Through these, he can look at a cross-section of the plant and down into the building's floor, where he can see the filter and other connected components. He then zooms in on the filter and sees the associated component information, and he notices that the flow through the filter is uncommonly low. He immediately proceeds to the downstairs room and starts cleaning the filter.

Augmenting the object

As part of his daily round, Bob is checking the area around the sludge tanks and notices that the surface water in the tanks is brownish. He walks over to the tank display to get more information. It shows the flow is uncommonly low through filter SK-71 (and suggests the filter be looked at). He immediately proceeds downstairs and checks the primary values for the filter on the filter display, which confirms a massive build-up, and Bob starts cleaning the filter.

Augmenting the environment

As part of his daily round, Bob is checking the area around the sludge tanks and notices that the surface water in the tanks is brownish. He speaks out a command to display the system information, which is then projected down onto the water surface. Seeing that the flow is uncommonly low, he gives an order to show the sub-system of which the tank is a part. A diagram is projected onto the surface clearly indicating a problem with the SK-71 filter directly connected to the tank. He immediately proceeds downstairs to clean it.

Making tests – augmented scenarios

In these scenarios the underlying assumptions are the following: the wastewater treatment plant now has access to sensors that provide continuous analysis of the contents of nitrate, ammonium and phosphor in the water at three separate parts of the process. Furthermore, equipment for measuring the amount of organic matter as well as the amount of dry matter in the sludge is also available.

Augmenting the user

7:00 a.m. Joe picks up his hand-held lab computer and goes out into the plant to start his round. He goes down to the inlet and connects the mobile computer to the automatic water analysis system. The mobile tool shows the sensors have been working impeccably through the last 24-hour period, and he then downloads the list of analysis values for the nitrate, ammonium and phosphor in the inlet water to his mobile lab computer. He then proceeds to the secondary setting reservoir and the post setting reservoir in turn, and picks up the associated nitrate, ammonium and phosphor concentrations. In the building with the automatic analysis equipment for the post setting reservoir, Joe meets a colleague and says hello as he passes by. Now all he needs to do is to go by the biological sludge tanks to check the results from the equipment there. He downloads that information as well and then takes the lab computer to the control room where he connects it to the main computer and downloads the information to the system.

Another colleague, who works in the building next to the old lab, calls Joe over to tell him that the contents of the primary clarifier looks strange today: almost as grey as cement. They briefly discuss what could cause this and Joe takes out the hand-held lab computer to look at today's result more closely. They all lie well within the permitted range despite the strange-looking grit, so they agree there is no need to do anything out of the ordinary.

Augmenting the object

7:00 a.m. Joe goes out into the plant to start on his round. He goes down to the inlet and looks at the inlet display to look through the analysis log for nitrate, ammonium and phosphor that has been collected through the past 24 hours. He also checks that the sensors have not given any alarms. The analysis results are automatically sent to the main system, where they are stored. He then proceeds to the secondary setting reservoir and the post setting reservoir, repeating the checking routine. In the building with the automatic analysis equipment for the post setting reservoir, Joe meets a colleague and says hello as he passes by. Now all he needs to do is to go by the biological sludge tanks to check the results from the equipment there. He finds no anomalies in those results either, and so his round is completed within 20 minutes

Another colleague, who works in the building next to the old lab, calls Joe over to tell him that the contents of the primary clarifier looks strange today: almost as grey as cement. They briefly discuss what could cause this and decide that the best cause of immediate action is for Joe to look through the results from the sensors when he gets back to the control room (or the setting reservoirs). Joe goes into the control room where he can get access to all the information and is able to compare the sensor output from the various checkpoints. They all lie well within the permitted range despite the strange-looking grit, so he decides there is no need to do anything out of the ordinary.

Augmenting the environment

7:00 a.m. Joe goes out into the plant to start on his round. He goes down to the inlet well and speaks a command to display the sensor logs, one by one. The information is projected down onto the water surface, and Joe can browse through them using other verbal commands. He then proceeds to the secondary setting reservoir and the post setting reservoir where the repeats this procedure. In the building with the automatic analysis equipment for the post setting reservoir, Joe meets a colleague and says hello as he passes by. Now all he needs to do is to go by the biological sludge tanks to check the results from the equipment there. He finds no anomalies in those results either, and so his round is completed within 20 minutes

Another colleague, who works in the building next to the old lab, calls Joe over to tell him that the contents of the primary clarifier looks strange today: almost as grey as cement. They briefly discuss what could cause this and decide that the best cause of immediate action is to take a through look at the logs. They walk inside to the primary clarifier and Joe calls up a map of the wastewater treatment plant showing the primary clarifier and the three sensor points, which is projected onto the wall. He then specifically calls up the log information from the sensors, which are then projected onto the wall, superimposed on the map. Joe and his colleague confirms that all the sensor values lie well within the permitted range despite the strange looking grit, and they decide there is no need to do anything out of the ordinary.

Augmented reality based computer support in mobile substrates

We have proposed six future scenarios based on the two original work scenarios and the three technical approaches to augmentation. The next step is to consider how the scenarios lead to computer support for distributed process control, implemented in mobile substrates. Using a mobile tool for supporting work at a wastewater treatment plant seems, from the definition of the three types of augmentation, to be a clear-cut case of augmenting the user; it is a hand-held device to obtain information about physical objects. However, through the examples below, we explore the use of mobile technology for supporting wastewater treatment work in relation to all the augmentation aspects. We have used the future scenarios from the previous paragraph as an inspiration for the considerations voiced in the following.

Augmenting the user

Equipping users with mobile devices may provide them with system- and component-specific information locally rather than centralised through a PC in a control room. It becomes possible to get feedback immediately, for example hear a motor change pitch when you adjust the speed or effect. In our ‘brown water’-example, a mobile tool could have been used to call up component-specific information about the water tank and following show which components it is, physically and process-wise, connected to. In the lab-example, a mobile tool was used in the ‘augmenting the user’-scenario, enabling the wastewater operator to view the measurements from the on-line sensors. However, it is far from trivial to suggest a satisfactory implementation of this, that will ‘allow the user to see the relevant information in a given situation’. This relies on being able to communicate which component we are interested in looking at and when, and to visualise or at least describe the networks of connections of which a given component is part.

Augmenting the object

Using mobile devices in relation to augmenting the object also provide us with some interesting insights, of which we shall give two examples. We may consider a situation in which a component has had a breakdown and thus requires special monitoring after repair. A mobile device is then placed on the component and used as a temporary display/control device for the component after it is put back into operation. The worker responsible for the area with the component now has local control and surveillance handles for the component integrated into his work routines, for example the daily round. Furthermore, if we look at the definition of what it means to augment the physical object, as given in (Mackay 1998), there is an implicit call for embedded software in the physical objects. This sounds quite clear-cut, but the borders between what is augmented are blurred if we regard the hand-held device we mentioned in the previous example of augmenting the user and add a power cord to solve the communication problem between the mobile device and the components. Is the mobile device now augmenting the user or the object?

Augmenting the environment

Augmenting the environment with mobile devices also yield important factors we have to regard, as we will show with the following example. Consider a situation in which a motor has broken down. A worker is sent out to repair it, either because it is part of his area of responsibility or because he is a specialist. With him he carries his mobile device, that he uses on location to display the primary properties for the motor, making sure it has been properly shut off before he starts disassembling it. He places the mobile device on the ground and accesses a blueprint of the type of motor he is working on. The mobile device now tracks his movements, the motor and all the disassembled pieces on the ground. It also projects the drawing up into the air or onto a wall, indicating the damaged part of the motor. When the worker picks up a specific part, the associated area on the blueprint lights up, aiding the worker in the repair and subsequent re-assembly of the motor. In this example the mobile device has the capacity to augment the user, the object and the environment and the example holds true for less complex procedures as well, such as cleaning a clogged filter.

Considering the examples above we conclude that using one perspective strictly and disregarding the other two when applying the perspectives to design might very well yield a result. However, it is imperative to consider the artefact we are designing to support a given work practice through all three perspectives to evaluate when the borders between perspectives no longer exist, and let this guide our design solution. As such, the division into three basic strategies is an artificial construction, based solely on a division in interaction modes. The three approaches to augmented reality are based on the assumption that function and interaction can be meaningfully separated in software design. However, the question is whether such a complete separation is possible; the examples just shown suggest it be not.

Conclusions

We have presented a collection of future scenarios for augmented reality based mobile technology based on situations from an empirical study of wastewater treatment work. Based on the application of the three technical approaches to design of augmented reality (Mackay 1998) the paper provides an alternative to the straightforward idea that mobile technology is mainly a matter of enhancing the user. As the presented future scenarios are rigidly based on the three technical approaches to augmentation it must be expected that many important aspects of wastewater treatment work be neglected. Thus, in a situation of doing design this perspective alone would be too limited. However, the three technical approaches to design of augmented reality seem to be fruitful metaphors in the design of mobile technology if used in a manner not displacing focus away from the more important work oriented issues.

With respect the design of mobile support for process control work, our analysis point to three key issues: augmentation, context and dynamics.

The three technical approaches to *augmentation* induce a differentiation of types of mediation pointing beyond the technical classification of interaction devices on which the approaches are based. Thus, emphasising that the specifics of mediation are not determined by the technical substrate for the relevant artefact as much as they result from how the artefact is incorporated into the concrete activity. Because specific use instances changes the mediational role of a mobile artefact, moving it amongst the roles of augmenting the user, augmenting objects and augmenting the environment, this points to the general dynamics of artefacts mediating human activity (Bødker 1991). The separation of interaction and function proves to be problematic in that it detaches use from the contents of the work situation. In the case of wastewater treatment, the trend towards distribution of the automation control system into the plant by means of embedded software, advanced online sensors and wireless networking of components, changes the conditions for creating augmented reality based interaction, and more importantly changes wastewater treatment work itself.

Context is a particularly important issue to address in designing mobile support, which is illustrated in the future scenarios for augmented reality based design of mobile support. Physical location in the domain is the most obvious and also the most simple to handle; with bar coding of components, or more advanced techniques. Unfortunately, there is more to context than mere physical location in a hierarchical technical layout. The scenarios of the study indicate that the same component in the plant can play different roles for the same worker according to actual work context. A specific wastewater operator may be interested in one set of information and one range of controls over a specific component in the context of his daily inspection round, whereas he will need another set of information and control in the situation of a machine breakdown. To have access to all information and control is impractical, as it will put an enormous navigational load on the operator. In the mobile situation, this impracticality is emphasised by the size of displays, the limited interaction, and the need to handle other pieces of equipment in the use situation. Thus, solutions are to be found in the continuum between systems that intelligently determine context (not that realistic) and possibilities for the operator to choose between predefined context dependent modes of the mobile computer support.

Finally, the *dynamic* nature of a wastewater treatment plant induces a need for support that is flexible and adaptable (Bertelsen & Nielsen, 1999). The "wired wilderness" that is the wastewater treatment plant is changing on a day to day basis. Mobile support must seamlessly adapt to the change of configuration or must be insensitive to such change. Thus, we not only acknowledge the general unpredictability of work, but also add a similar dynamics with respect to technical configuration.

The next steps in the wastewater treatment project include workshops with workers from the wastewater treatment plants where we will simulate work with prototypes currently being developed. The prototypes are informed by the scenarios presented in this paper as well as more theoretically oriented analyses of the empirical studies, and will primarily serve as vehicles for testing our hypotheses about the domain and about computer support in the wired wildernes.

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