Designing for a Collaborative Industrial Environment: The Case of the ABB Powerwall

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Abstract

This paper presents the design of a collaborative interface for highly automated, industrial environments. The resulting system, the *ABB Powerwall*, consists of large, shared interactive displays and several personal mobile information technology devices. On-site service technicians can seamlessly move information back and forth from their mobile devices to the shared display. The system supports various kinds of collaborative work, including making annotations; browsing for information; and visualizing blueprints and three-dimensional representations of products and torrents.

The design vision has been to provide end users with an unobtrusive way of sharing information, discussing problems and issues with others in front of a large collaborative screen, and the chance of socializing and learning from each other. Located strategically in the specific environment for which it has been designed, the ABB Powerwall is intended to become a natural gathering point that increases interaction, afford gathering, discussions, collaboration, small talk, socializing, and community-making.

Keywords

Interaction design, industrial environment, collaborative work, collaboration, mobile devices, human-computer interaction, user experience, prototyping.

Project Statement

This design project takes off from within a larger movement—or even, a "paradigm shift"—in industrial use of information technology (IT). In many highly automated industrial environments such as car manufacturing sites and process industries, desktop computer-based information systems and traditional, closed-area control rooms are giving way to various more flexible and dynamic IT solutions. Often, these new systems are building on mobile technology that allows workers to be out in the field, physically present in the factory environment.

The move from desktop computer support systems to small, handheld mobile devices hence allows service technicians in industrial environments to carry with them access to information and services they previously could only access in dedicated control rooms, and be physically present within the production environment. While service technicians experience this as a positive development in general, actually using these new mobile devices in these environments however seems to pose a whole set of new challenges [8, 9, 10]. These include a set of usability issues having primarily to do with small screen displays and limited and cumbersome input devices, as well as some technical limitations including poor computational power and limited bandwidth for data communication. We argue that these use-related issues, first, come to influence both *when* as well as *how* service technicians are using their mobile devices. Second, we also argue that the shift from shared and stationary desktop-based systems to personal mobile devices also come to influence the larger work practice of the group of service technicians as such.

Based on our previous studies of service work in industrial settings, we see that the increased individualization of computer use that the personal, mobile devices bring with them may in fact be counterproductive to the established work practice, which is permeated by physical collaboration and what we call "human-human-computer interactions".

The latter case is a common way of working in these environments, where two or more service technicians gather in front of a computer screen and together discuss some issue, hence both facing the same screen, the content of which becomes a shared reference for discussion [cf. 5, 12, 24, 25]. An important incentive for this design project has been that if everybody is equipped with a personal, mobile device, these shared and collaboration-affording screens could come to disappear, and with them shared points of reference leading to fruitful discussions between service technicians. Based in our studies, we believe that these screens—and a known, physical location in the environment—play a vital role in the current work practice, as they afford gathering, discussions, collaboration, small talk, socializing, and community-making [5, 12, 15] in a way that a small palm-sized, personal display does not.

With this in mind, the main design problem that this project set out with was: how do we provide the mobile service technicians with the same or even better means of collaboration and cooperation than the shared screens they have access to in their old control rooms?

Background

The design of the ABB Powerwall builds on results from our previous studies. First, we have for many years been involved with the Swedish-Swiss industrial company ABB and many of their customers in user-centered interaction design projects. One such project resulted in a prototype implementation of a mobile support system for service technicians at highly automated industrial sites, focusing on novel services and new kinds of interaction styles suitable in such a use context [9, 10]. This system allows service technicians to carry with them a way of accessing information they had previously only access to from their desktop computers. One experienced weakness of this mobile support system however, building on palmtop-sized computer technology, was the limited support of collaborative means; the difficulty in sharing information with others; and the problems of providing text-based input.

Second, in a fieldwork study using ethnographic techniques conducted at two large vehicle-manufacturing sites powered by ABB technology—Volvo Trucks in Umeå, Sweden and Volvo Cars in Gothenburg, Sweden—we found that there in these environments is a need for co-located physical collaboration (co-presence) as well as for ad-hoc meetings and briefs [8]. While some authors note that work in industrial settings have come to resemble office work in some respects [14], we insistently argue some perceived differences in the work carried out by the studied service technicians and that what is expected of office workers, and argue that these differences should be capitalized on in an appropriate design of a computer support system.

One such difference regards the nature of collaboration. While office workers too have a need to collaborate, we however believe that what is meant by collaboration and how it is best facilitated often differs between the white-collar world and the blue-collar world. While useful office-type of collaboration is often asynchronous, distance spanning, and technologically mediated, we have come to understand collaboration in the industrial settings we have studied as having the character of synchronous, collaborative, and being co-present in the physical world. The latter is important, as collaboration between service technicians is largely situated in the physical world. The service technicians' shared objects of concern are often physical objects, and frequent discussions take place between service technicians in the physical proximity of the concerned object. Service technicians often need to use their bodily skills and strengths to lift or maneuver devices, and they often show each other how something is done in a very direct sense, for instance explaining how a robot is to be reprogrammed by showing how it is done.

Our initial vision for this design project was that rather than building office-type of collaborative support directly into the mobile system itself (such as instant messaging), we should try to compensate for the perceived weakness of the mobile devices in terms of collaboration by adding public displays to the actual physical environment. These public displays would be designed to afford collaborative work in the same way as do the public displays in the control room, hence act as a natural gathering point; a place for communication and talk, discussions and advice, a meeting point. Hence, our main design strategy has been to create a "digital environment" through the use of *supportive technologies*—rather than regarding the mobile support system as a standalone system or as a *substitute* to stationary solutions.

The Process

This project grew out of a long-term collaboration on many different levels between Umeå Institute of Design at Umeå University, Sweden, and the industrial company ABB and a number of their customers. As introduced above, the incentives for this particular project came from the findings of two previous studies. Based on these findings and a shared vision on the importance of encouraging collaborative work in these environments, a small design team was established to quickly come up with a prototype implementation of a possible future system or product. It consisted of a senior design researcher who acted as the project manager, and two interaction designers. During the design process, two design research assistants each with specific technical competence were also tied to the project.

To be able to prototype a system, do some testing, and have a functional demo system available in a period of six weeks—which was the time frame provided—the design team decided to apply a fairly straightforward and user-centered interaction design strategy. To begin the process, the design team gathered to discuss the problem area, its boundaries, and some of the project's ingoing limitations—its direction, scope, and aim; and what would be reasonable to expect to achieve in the time frame given to the project.

Design Challenge

If the main design problem, as stated, is how to provide the mobile service technicians with the same or even better means of collaboration and cooperation than the public screens they used to have access to in their old control rooms, and our answer to that is a to provide the users with an "integrated digital environment", then the main design challenges for such an environment built to ignite and support collaboration must primarily be to have it *accepted* by the intended end users; the service technicians. This is a fairly simple argument; if the end users do not accept a system, the system will not be used, and if the system is not used it will not support collaboration.

To have the system accepted, we reasoned that the user interface and especially the interaction between the mobile support system and the collaborative display would be very important factors in providing the chance of a good user experience. Hence, the project early on tried to define some of the characteristics of what such a user experience would embrace. These characteristics included:

First, there must be a simple yet effective way of moving information in between a service technician's personal mobile support system and the collaborative display. *Second*, the moving of information should be seamless, i.e. not requiring "docking", connecting cables, or any other unnecessary technological procedure that would interfere with the flow of work or be experienced as cumbersome. *Third*, the collaborative display should be large enough so that two or three service technicians can gather in front of it without getting in the way of each other. *Fourth*, the collaborative display's interface and features need to be controllable from the mobile devices as well as directly from interactional means located on the display itself. *Fifth*, all interactional means regarding the collaborative display, on the mobile device as well on the collaborative display, should be easy to use and require very little in terms of practice, expertise, and previous knowledge of the system.

Brainstorming, Mock-ups, and Prototyping
A number of brainstorm sessions then followed, each providing the design team with a number of ideas; some ingenious, some less so, some impossible, some conceivable, some traditional, and some futuristic. From the ideas being nurtured in these sessions, the basic notion of the ABB Powerwall began to emerge.

From this basic notion—to apply a combination of large, stationary screens that are shared and small, personal and mobile handheld devices—the design team began the design process. Here, a series of simple mock-up prototypes using a whiteboard and a switched-off PDA proved to be a very effective way of getting feedback at a very early stage in the design process. Both the PDA and the whiteboard contained cut-out sections of the user interface drawn on paper, which was dynamically changed by members of the design team based on user action. This proved to be a very useful way of getting feedback as to the users' experience of the system as a whole as well as detailed feedback on usability, interface layout issues, and system features. While 'users' at this stage for the most part meant students and all kinds of miscellaneous people we found in and around the design school—who acted as substitutes for real end users to speed up the process—these early and partly participative mock-up sessions nevertheless provided the design process with vital information. In fact, in retrospect these sessions turned out to be one of the most important parts of the whole design process, really guiding our final design.

After having prototyped the system through a series of mock-ups, the design team felt confident in moving into the process of transferring our ideas and the lessons we had learned into a technical platform.

In this process, the project team's research assistants became more and more involved in the project. Given the very short period of time available for implementation, the technical prototype implementation (described in more detail below) focused on providing its users with suitable user experiences, based in the mock-up work, rather than with a fully functional technical backbone, inclusive of all the various database interfaces and so on that would have been required by a fully functional system to become used in daily operation at a highly automated industrial site.

Related Work

In the Human-Computer Interaction (HCI) and Computer Supported Collaborative Work (CSCW) literature, we find that the use of large, interactive displays as a platform to support spatial organization of information, task management, and collaborative work is far from new. It has been explored for many years by a number of research teams, including [7, 11, 18, 20, 22, 24]. Other work related to collaborative aspects of our system includes such various issues as differences between co-located and remote collaboration [19], how large displays can come to entice collaboration and interaction and how people respond to large displays [3, 24], collaborative knowledge management [6], and collaborative content creation [2].

One should note, however, that most previous efforts in this direction take off from perceived problems and opportunities arising in typical white-collar settings, such as office environments or traditional meeting rooms. The primary end user is most often assumed to be a so-called 'knowledge-worker' [17].

Figure 1. A series of pictures from the early stages of the user-centered interaction design process.

A mock-up prototype of the system was achieved at a very early stage in the design process by using a whiteboard as the large collaborative surface and a switched-off PDA covered with sheets of paper containing the personal mobile interface.

In light of this, we believe our project has two important contributions. First, we establish, exemplify, and discuss the use of large, interactive collaborative displays in a non-typical use setting, that of blue-collar workers within vehicle manufacturing. These users and their context presented the designers with a set of new challenges, generally not covered by previous research. While this is not to say that the blue-collar world is wholly unexplored in terms of research (in the area of CSCW especially, a number of studies have looked into work and collaboration in such contexts, including [1, 13]) we nevertheless believe that what makes our study different is that we, already from the start, have had a design perspective rather than primarily an ethnographic interest. Second, our prototype system proposes and implements a seamless interface between the service technicians' personal mobile devices and the shared, stationary collaborative display [4, 16]. This seamless interface allows information to be exchanged easily in between the mobile device and the collaborative screen by means of simple, physical interactional techniques. In designing the style of interaction used in the project, we have been particularly influenced by some previous efforts in this area [21, 22].

The Solution

From a mere technical perspective, an ABB Powerwall consists of several devices communicating with each other over wireless LAN, including a large back-projected display (10 × 6 feet), a pen-tracking device to make it interactive, a mobile support system building on PDA technology, a position tracking system, and a server system connecting all the parts of the system. But from another, and perhaps more interesting perspective, the wall-sized display and the interaction that takes place between the interactive display and each user's mobile device constitute the interface to which users are exposed. Thus, each user has a private personal display on the mobile device as well as a large shared display. A service technician in front of the shared display can seamlessly move information back and forth between his or her mobile support system and the ABB Powerwall. This is done literally, by physically 'picking up' pieces of information from their mobile devices and placing them directly onto the wall-sized display. The system then supports various kinds of collaborative activities, including making notes and annotations, browsing for information, and visualizing blueprints and 3D representations of products or torrents. The objects dropped on the display may then be picked up again and put back on the service technician's mobile device.

Functionality and User Interaction

As the above scenario suggests, the ABB Powerwall supports a number of different user activities:

Exchange Information Seamlessly

Using a pick-and-drop style interface [21], users can move information to and from their personal mobile devices and the ABB Powerwall. This information may have been collected using a similar technique from somewhere in the factory environment.

Hot Spot Area

The physical area in front of the ABB Powerwall is an active space, in that the prototype system responds to one or many service technicians being inside of it. The system recognizes their identity and allows them to drop or collect information from the screen.

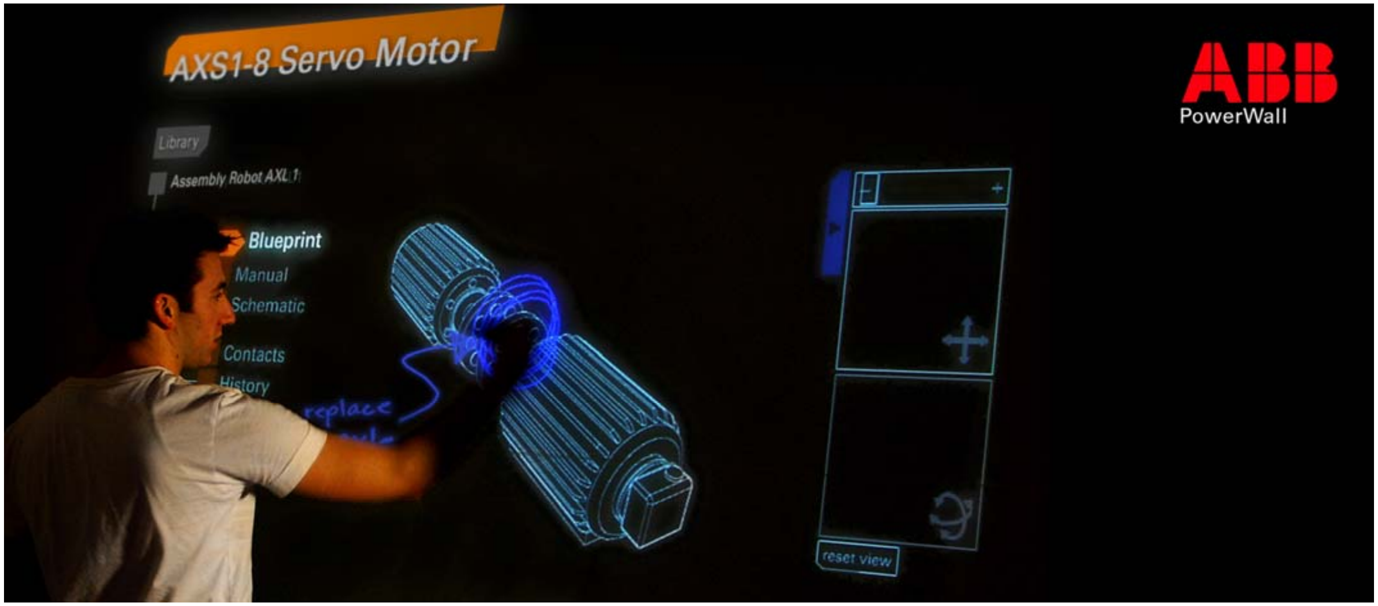


Figure 2. A user in front of the ABB Powerwall display is annotating a three-dimensional model

Browse and Navigate for Information

When an item—corresponding to a physical or virtual object in the factory—has been dropped on the ABB Powerwall, the system supports the user in browsing and navigating information connected to the item.

First, users may view a 3D blueprint or a wire frame model of the item. This model may be rotated, moved, and zoomed. This can be done both from the mobile device (used as a remote control) and/or from interface widgets located on the ABB Powerwall screen. This allows two or more people to operate the screen simultaneously without resorting to turn-taking.

Second, users may switch back and forth between the 3D view and a two-dimensional schematic representation of the same device.

Third, users can retrieve and examine text-based information about the device, such as its manual, contact information to its producer, information about maintenance history, etc. This information can also be annotated.

Fourth, users can retrieve information about subcomponents as well as other components related to the currently active device.

Figure 3: A screenshot from the ABB Powerwall.

This snapshot (taken during the development process) is presented here merely as an example of the graphical interface that users of the ABB Powerwall are exposed to on the 10 × 6 feet display, but should nevertheless provide a clue to the user experience.

In the middle of the screen is a three-dimensional representation of the currently active object (AXL1-14).

To the left is a tree-like structure giving users access to various kinds of services and information connected to the currently selected AXL1-14 object, as well as subcomponents and other objects in the factory connected or related to that object.

Top right are on-screen interface widgets for controlling and manipulating the three-dimensional model.

Bottom right are visual cues to the three service technicians currently present in front of the ABB Powerwall (all of which are mysteriously named Bosse in this early development screenshot)

To the left of these are objects that have been dropped on the ABB Powerwall, where the currently active one is highlighted. All of these can be picked up and put back on the mobile device by any of the service technicians in front of the screen.

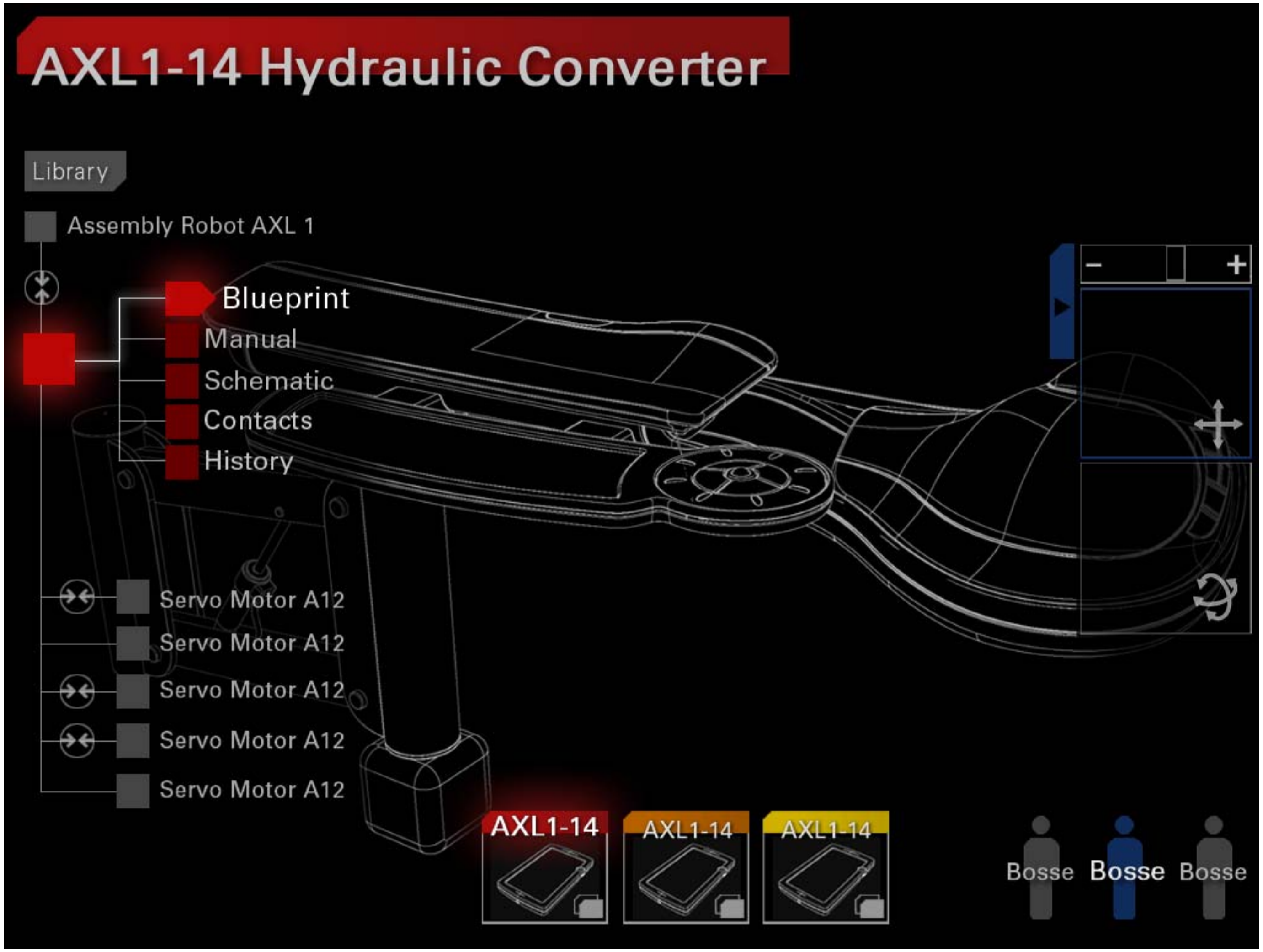


Figure 4: A screenshot from the interface presented to the user on the personal mobile device when in front of the ABB Powerwall. The interface widgets for controlling and manipulating the currently active object (AXL1-14) are the same on the personal device as they are on the large, shared display.

ANNOTATE INFORMATION

The whole of the ABB Powerwall can also be used as a whiteboard, allowing service technicians to annotate all blueprints, 3D models, and text based information, or to just quickly scribble down names, phone numbers, TODO-lists, and so on. While this information is saved to the currently active object, our current prototype implementation does unfortunately not yet support viewing the annotations on the mobile device.

Hardware and Software Implementation

The hardware used to implement the prototype system consists of: a server equipped with Wireless LAN (WLAN) cards, Pocket PCs equipped with WLAN card (*HP/Compaq iPaq 3850*), a high-resolution video projector, a back projection screen, an *eBeam System 1* whiteboard capture system, and the *Ekahau* WLAN positioning system. The software consists of a flash application for the server and the ABB Powerwall displays; flash applications for the Pocket PC; and server software written in Perl, handling the communication between the different parts of the system.

Communication between the flash applications is achieved through the use of XML sockets. As two Flash XML sockets cannot communicate directly, a helper application is needed for relaying data. Thus, each flash application sends XML formatted data to a server written in Perl that forwards the data to the other Flash application. Physically, data is transported through a WLAN (802.11b) network.

The physical area in front of the ABB Powerwall forms a hot spot, meaning that the system recognizes who is in front of the screen and allowing that person to drop information on it. This is achieved using a WLAN positioning system from Ekahau, tracking the position of each user's mobile support system.

Furthermore, the prototype system captures user interaction on the large display using eBeam, which is a whiteboard capturing system that employs ultrasound to determine the position of pens quite accurately and rapidly. Two receivers are attached to the top of the capture area and a pen-holding device equipped with ultrasound transmitter is rigged to emit a signal whenever the tip of the pen is pressed against the surface being tracked. The position of the pen is calculated through bilateration many times per second.

Use Scenario

The following scenario gives an overview of the ABB Powerwall system and introduces one way in which it can be used for collaborative purposes by the service technicians. It is important that this scenario is not seen as a proof-of-concept for justifying the system, but rather as a *demonstration* of the concept. It walks the reader through a situation in which the ABB Powerwall could be used. But as the ABB Powerwall is designed to be an open system affording collaboration and has many possibilities, many of which probably go far beyond those for which we knowingly designed, this scenario should be considered as only one possible way of making use of the system.

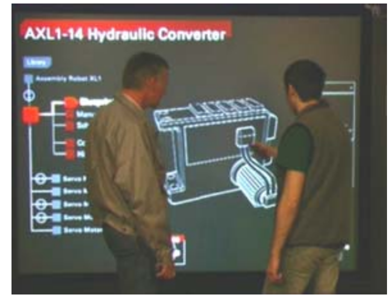
Nevertheless, it will point the reader towards what we believe are some of the system's most important characteristics: its ubiquitous presence in the physical environment and the immediacy and informality of use.

1. A service technician, Joe, stands in front of a malfunctioning device. He has good knowledge in how to operate the device, but it is now behaving mysteriously. Joe is unsure which part of the device is malfunctioning.

2. He brings out his personal mobile support system. By holding it close to the device, the system knows which device it is and an icon appears on the screen. Joe grabs this icon and stores it by placing it in a dedicated screen area called the "bucket".

3. With the device stored in the “bucket” on his personal mobile support system, Joe heads for the ABB Powerwall collaborative display. On his way there, Joe stumbles upon Harry, and asks him to come along to help him find out more about the mysterious problem.

4. When in front of the ABB Powerwall, Joe picks up his mobile support system, and physically grabs the malfunctioning device’s icon that he has previously stored in the bucket, and drops it on the wall.



5. The ABB Powerwall recognizes the icon being dropped on it, and displays information about this device. Firstly, Joe and Harry review a three-dimensional model of the malfunctioning device. The ABB Powerwall allows them to perform various kinds of manipulations including zooming, moving, rotating, and making notes and annotation directly on the screen.

6. Together, Joe and Harry find out that the device suffers from electrical problems. They bring up the device’s blueprint, and Harry marks the spot where the problem originated. Joe is then able to grab the device’s icon from the wall and put it back into his mobile support system. All the annotations they made are now stored in Joe’s mobile device. He heads back to the malfunctioning device to carry out the necessary service work.

Discussion

The ABB Powerwall is a collaborative display designed to try to answer to the perceived need for large, shared displays to be introduced to the industrial environment, based on studies of service work at two large vehicle manufacturing sites. These industrial contexts are undergoing a shift from relying on desktop-based IT support systems to a personal, handheld mobile support system. While this change in computing paradigm solves many issues and obstacles in their old work practice, it has at the same time come to create a whole set of new problems that have to do with what seems to be inherent properties of the new computational tool to which they are exposed. The ABB Powerwall tries to deal with some of these new problems.

One of these is the problem of sharing of information and allowing collaboration between co-located people. Their new, mobile PDA-sized computers seem to not support the kind of co-present collaboration which seems to be a very big part of the work practice of the service technicians. By adding physically fixed wall-sized displays to the factory environment, which the service technicians easily can understand and use, a natural gathering point has been created. Preliminary observations of this system in use, and the input gathered from users during the mock-up phase especially, suggest that it could actually come to enhance the sharing of information between different categories of workers, not just between service technicians.

Future Work

While the ABB Powerwall prototype installation is a demonstration of the concept, future prototypes and that will be installed in a factory setting and used on a day-to-day basis in actual production work will come to serve as proof of concept. For this to take place, we are currently starting up a continuation of this project that will run over three years and which will implement an enhanced and fully functional version of the ABB Powerwall at one of their customer's site, integrated it with their existing information systems and databases.

Among other things, this will allow us to do more proper and longitudinal evaluations of the system with (real) end users in a more natural use setting than our own lab. So far, the ABB Powerwall system has in fact been exposed to a number of real service technicians, other industrial personnel, as well as professional interaction designers, in several informal group sessions in our lab (which we have knowingly avoided to dress up as 'focus groups' in this paper). Despite their very informal character, these sessions has nevertheless provided us with a lot of useful feedback, including various kinds of usability issues, additional services wanted, unnecessary information provided, etc. This information will be very useful for the future development of the ABB Powerwall, but it was not within the boundaries of the project presented here to make another design iteration.

An important part of the next stage in the ABB Powerwall project will be to follow end users around and see how the system integrates into their day-to-day activities. In our view, this could be a way in which we could gain insight into what we believe are some of the ABB Powerwall's most important characteristics—its immediacy, its ubiquitous presence, and its informal character.

This will provide empirical data of how the system is actually being used in practice for solving real problems, outside of the maybe confining and artificial focus group settings, scenario problem solving, and lab tests. We believe such insight will allow us to take the prototype further and refine and reemploy it to meet end user needs.

Conclusions

We have presented the design of a collaborative interface for industrial environments, the ABB Powerwall, which is a collaborative interface for industrial environments consisting of several elements. Each user is equipped with a personal mobile device supporting their day to day activities. To support this, the ABB Powerwall is a large, interactive, and collaborative display which is fixed to a physical location in the industrial environment. On-site service technicians can seamlessly move information back and forth between their personal mobile devices and the ABB Powerwall. The system supports a seamless pick-and-drop interface between each user's personal mobile device and the ABB Powerwall. For manipulating and creating information on the wall-size display, the ABB Powerwall allows users to view text-based information; to move, rotate, and zoom in and out on graphical blueprints in 2D and 3D; as well as making annotations to existing information or just quickly write notes.

The underlying idea behind the ABB Powerwall prototype effort is to provide a fairly unexplored user group, when it comes to interaction and user experience; service technicians, an unobtrusive way of sharing information, discussing problems and issues with others in front of a large collaborative screen, and the chance of socializing and learning from each other.

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Acknowledgements

We would like to thank ABB Corporate Research for funding and support, and Oskar Fjellström and Peter Lundholm for their technical expertise. The ABB Powerwall is currently patent pending. This design research project has partly been made possible through a research grant from VINNOVA.