Desituating Context in Ubiquitous Computing:
Exploring Strategies for the Use of Remote Diagnostic Systems for Maintenance Work

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ABSTRACT

Context awareness forms a core concern in ubiquitous computing and goes hand in hand with today's extensive use of sensor technologies. This paper focuses on the use of sensors as part of remote diagnostic systems (RDS) in industrial organizations. The study shows that the process of desituating context, that is, capturing context and transferring it to another context, is critical for the successful use of the technology. The processes of capturing and transferring context are explored in industrial maintenance work through interviews with suppliers and users of RDS. To successfully manage the desituation of context, industrial organizations must find strategies of creating and managing a center of calculation, a center where the captured contexts meet and merge. To enable the long-distance control of the equipment, all data must be compiled into one manageable view without losing the specifics of the local contexts. The data collection must be designed with this in mind. Moreover, to bridge the gap between the digital and the physical world created by the new way of organizing the maintenance work, a new kind of maintenance network must be formed, one in which local technicians' practices are reconfigured and instituted.

Keywords: *Context Awareness, Desituation of Context, Maintenance Work, Remote Diagnostic Systems, Ubiquitous Computing*

INTRODUCTION

Context awareness forms a core concern in ubiquitous computing and goes hand in hand with today's extensive use of sensor technologies in industrial organizations. As noted by Dey et al. (2001), sensors enable close attention to detail in their context and allow for automatic data collection. However, capturing context is not enough in ubiquitous computing environments. In this paper, we will see that desituating context – capturing context and transferring it to another context – is essential for ubiquitous computing use. This paper focuses on remote

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diagnostics systems, an application family within ubiquitous computing (Lyytinen & Yoo, 2002b). To date, the use of RDS has primarily focused on enabling effective and timely equipment maintenance (e.g., Jonsson et al., 2008). Sensors and network access are installed into equipments – mostly equipments and engines in industrial settings – to collect and access data remotely related to their performance. Critical performance indicators of industrial equipment can be monitored to ensure continuous and satisfactory performance and to guarantee timely and cost-effective maintenance. With RDS, centralized service centers can monitor and diagnose a large number of equipments remotely. Maintenance groups at these service centers engage in problem diagnostics and solving as well as value-adding services such as learning from failures and formulating forecasting models for equipment performance (Kuschel & Ljungberg, 2004; Tolmie et al., 2004).

RDS is often viewed as a harbinger of a new kind of practice that offers new possibilities for organizing maintenance. Improved uptime and lowered cost motivate the organizational use of RDS immersed in new settings and equipments. The impact of this technology may be observed in new work routines that separate technicians and the monitored equipment over time and space. In contrast to traditional maintenance, where local skilled workers use their senses and local data as the main source of information during maintenance, remote diagnostics depend on the content and quality of data plus the process of collecting and transferring it to the remote service centers. Local maintenance work has also been shown to be organized around communities characterized by collaboration and information sharing (Brown & Duguid, 1991). RDS reach beyond these local practices by transforming equipment's physical condition into a digital representation, which is then transferred from the local setting to a remote site for analysis. To this end, context is desituated: captured and transferred to another context.

The term "context" can seem obvious but at the same time obscure. Commonly, people find it hard to elucidate what it is, and in attempts to explain its meaning, synonyms as background, situation, milieu, and environment are often used. Dahlbom and Mathiassen (1993) argue that our understanding of context varies between individuals' own choice of underlying thinking and perspectives. Hence, context could be understood as a perceptual condition that to some extent is flexible and negotiable rather than a factual environment.

In context-aware computing, typical context information is: location, identities of nearby people and objects, and changes to all these things over time (Dey, 2001; Schilit, 1995). Dey (2001, p. 5) elaborates the definition of context as "any information that can be used to characterize the situation of an entity. An entity in such a view is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves."

Contextualism in organizational change means that events should be explained within the context of their occurrence (Pepper, 1948). It views organizational life as complex with interconnected events and continuously changing patterns. In this tradition, context is dichotomized into the outer and inner contexts of organizations (Pettigrew et al., 2001). The outer context includes the economic, social, political, and sector environment. The inner context is defined as features of the structural, cultural, and political environments through which ideas and actions for change proceed. The widely adopted socio-technical approach to information systems (IS) research on organizational change has been criticized for its limited view of context, its narrow perception of the duration and scope of innovation, and its sociologically naive view on technology innovation and social change (Avgerou, 2002). She emphasizes that the dynamics has to be studied as a situated emergent phenomenon, in which actor-network concepts provide a valuable analytical approach. The translation processes need to be understood by analysis of the relevant institutional contexts and their interactions.

In this study we deal with context-aware computing as well as contextualism in organizational change. RDS generate some of the new challenges associated with the interpretation of the computing context. Grudin (2001, p. 284) says that sensors "…can pick up some but not all context that is acquired through senses. Some context is lost, some is added, and captured context is presented in new ways… Missing or altered context disrupts our processing of information in ways that we may not recognize." RDS give insight into the complexity of working with contextual information, and the focus on equipment and their condition expands context beyond the current focus on individuals and their location and identity (Abowd & Mynatt, 2000). While desituating context is an essential ability for many ubiquitous computing application (Andersson & Lindgren, 2005; Lampe et al., 2004; Olsson & Henfridsson, 2005), current research has not explored this ability from an organizational perspective in any detail. This paper will contribute to this gap in research by exploring how the process of desituating context is managed in organizations using RDS. ANT is applied as an analytical lens for the contextualist inquiry into the use of an advanced RDS in six organizations.

To understand technology in a social context, it is important to focus on the relationship between technological artifacts and technology-in-practice (Hanseth et al., 2004). By conceptualizing the world as heterogeneous socio-technical networks, ANT can help analyzing and understanding the intertwined relationship between human agency, technology, and contexts to further our knowledge about desituation of context. ANT has gained increased interest in IS research (Holmström & Robey, 2005; Jones, 2000; Mähring et al., 2004; Walsham, 1997; Wickramasinghe et al., 2007). Applied to studies of IT, ANT guides the investigation of networks of people, organizations, software, and hardware (Latour, 1996; Walsham, 1997). For example, Moser and Law (2006) use ANT and argue that information in healthcare is fluid, referring to it being open, uncertain, in process and unstable. Mort May and Williams (2003) show how remote diagnosis in healthcare was made possible by the quality of the inscriptions of patients created by the nurse intermediaries. Walsham and Sahay (1999) analyze the development and use geographical information systems (GIS) in district-level administration in India. Their analysis shows that none of the districts studied created stable heterogeneous networks with aligned interests related to GIS. Consequently, the Western GIS was not adapted to the local Indian settings and Walsham and Sahay's (1999) study is a good example of ANT's principle that social and technical stability resides in the mutual dependency between technological properties and social context.

In the next section, we will review previous research on ubiquitous computing and draw on the ANT notions of action at a distance and centers of calculation. We then present the research method and the organizations forming part of the case study. The empirical results of the exploration of how the process of desituating context is managed in the case companies are also presented. Based upon the empirical results in relation to the literature, we identify two issues for which organizations dealing with the desituation of context need to find strategies. Finally, we conclude the paper with a summary of the findings.

LITERATURE REVIEW

Ubiquitous Computing

The computer has moved from dedicated operating rooms, via the desktop into our homes, and has now reached the status of innate or invisible objects in our everyday environments. Ubiquitous computing devices that weave computing into the environment are characterized by simultaneous potential for mobility, increased levels of embeddedness (Avital & Germonprez, 2003; Lyytinen & Yoo, 2002a) and context awareness (Dey et al., 2001). Due to mobility and embeddedness, they harvests large amounts of contextual data from environments, users, and equipments and use them in intelligent ways both locally and remotely. By being mobile, ubiquitous computing separates data from technology instrumental in collecting it (Avital & Germonprez, 2003) and allows data transfer over time and space. These computing environments can support knowledge work (Davis, 2003) and enable new ways of working (Garfield, 2005), learning (Chae, 2003), collaboration (Grudin, 2003) and business processes (Giles & Purao, 2003; Medovich, 2003). From a business perspective, data about customers as well as access to the customer's context can give business opportunities to develop new offers, as the present ubiquitous technology gives companies data and knowledge that was not previously available (Gershman & Fano, 2005).

Capturing context and informing an application of the context is a key challenge in the field of ubiquitous computing (Dey et al., 2001; Grudin, 2001). As Grudin (2001) points out, context that is captured is by default removed from its original context. This process of capturing context and transferring it to another context is what we label as desituating context. Recent research on context-aware ubiquitous computing applications is mainly focusing on identity and location (Abowd & Mynatt, 2000; Dey et al., 2001; Grudin, 2003) as well as focusing on context as something physically connected to people (Olsson & Henfridsson, 2005). Henfridsson and Lindgren (2005), identify multi-contextuality of use as particularly challenging in the design of ubiquitous services. As ubiquitous computing follows its user while moving through different spatial contexts and shifting temporally between different co-existing computing contexts, "context switching" capabilities become critical to support the user. Context is here defined in relation to persons and the situations they encounter. In contrast, Dey et al. (2001) show that context can be understood in a broader fashion both in terms of focus and content than what is assumed by current ubiquitous applications. In contrast to many other context-aware ubiquitous computing technologies, RDS not only address the context issues of identity (i.e., the ability to identify and separate equipments from each other) and location (i.e., where a equipment is located), but also pay attention to status (i.e., a snapshot of the performance of a equipment/process) and time (i.e., data on how such performance varies over a certain period). RDS thus goes beyond context in relation to people by also focusing on equipments (things).

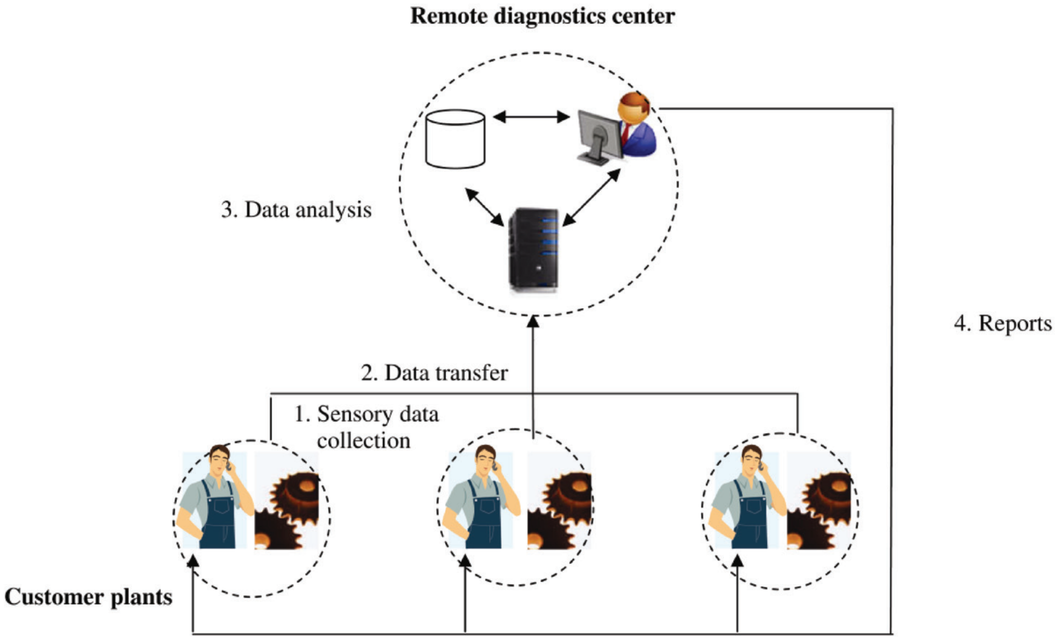
Figure 1 presents an overview of organizing maintenance work based on the RDS's ability to collect data in remote contexts. New interactions and tensions emerge due to a new type of relationship between the technology embedded in a equipment and remote technicians' access to generated information. This way of working need to be contrasted with previous maintenance models, which to a great extent are based on the physical presence of technicians. Through the use of RDS, context is thus desituated: captured in a certain context and transferred to a remote setting. At the remote service center, technicians are located working with analysis of data as a base for planning maintenance. This way of organizing maintenance work, separating information from its context, enables the remote technicians to act from a distance. In the following section, we will explore this possibility of understanding what it means to act from a distance and what issues become critical in such a process.

Action at a Distance and Centers of Calculation

ANT seeks to explain social order through the construction and transformation of socio-technical networks, i.e., connections between human agents, technologies and objects (Callon, 1986; Latour, 1987). The argument behind the inclusion of both humans and non-humans, and the ordering of these, is that the social is not simply human; it is intrinsically related to other materials too (Law, 1992). ANT has frequently been revised and extended, and there is, therefore, no unified body of knowledge. In Table 1, we summarize some of the key concepts in ANT (adapted from Walsham, 1997).

'Action at a distance' is a concept proposed by Latour (1987) to describe how actors influ-

Figure 1. Maintenance organization with the use of RDS



ence and control a remote context. What enables this process is the possibility of accumulating and transferring information about a remote object. During the information transfer, a translation process takes place. 'Translation' (Callon, 1986) implies transformation, which refers to how actors engage with other actors to generate ordering effects (Law, 1992). Translation goes beyond the traditional definition of action as it deals with mutual definition and inscription. When such translations get embodied into a medium or material, they are referred to as 'inscriptions' (Akrich, 1992). Such inscriptions prescribe a program of action for other actors.

A critical issue becomes how to render the contextual information mobile, presentable, readable and combinable with other pieces of information, a state referred to as immutable mobile (Latour, 1987). Such immutable mobiles (Law, 1987; Mol & Law, 1994) can move in

Table 1. Key concepts in actor network theory

Concept	Description
Actor (or actant)	Any material, that is, human or nonhuman actors
Actor-network	Related actors in a heterogeneous network of aligned interests
Action at a distance	How actors influence and control a remote context
Translation	How actors generate ordering effects by negotiating or maneuvering others' interest to one's own with the aim to mobilize support
Inscription	Embodied translations into a medium or material
Immutable mobile	A materialized translation that can be interpreted in essentially the same way in a variety of contexts
Center of calculation	A location for accumulation, synthesis and analysis of observations
Modes of ordering	Recurring patterns as part of the ordering of human and non-human relations

time and space while being interpreted in essentially the same way in a variety of contexts. Examples of such objects are writings, maps, graphs, figures, and formulas. Even though objects remain unchanged during their moves, locality and particularity are lost in the transfer from local to remote settings, while compatibility, standardization, and universality are gained (Latour, 2000). Translations can thereby make objects appear different to an individual at a remote site than it may appear to an individual close to the physical object.

'Center of calculation' (Latour, 1987) is a location for accumulation, synthesis and analysis of observations, i.e. collection of immutable mobiles. Examples of such centers of calculations are scientific laboratories or census offices. In these centers, information is accumulated about things, processes, people or places to facilitate prediction and control (Bloomfield, 1991).

According to Latour (1987) the information-accumulation process changes the relationship between remote and local actors. As the information goes from being locally situated to being universally applicable, the local actors lose their unique access to information, and the remote actors' position grows stronger. Consequently, the local actors are moved into the periphery if actions are not taken to make sure they are properly instituted in the network of remote actors and center of calculation (Bloomfield, 1991). The new information flows allow for new ways of organizing. The concept 'modes of ordering' (Law, 1994) is used to explain the multiple, often implicit, strategies and practices that hold an organization together. Organizing is about complex relations between the different modes of ordering (Law, 1994).

RDS are made up by a collection of technologies including sensors, which are diffused into equipments throughout a plant or a factory. The amount of contextual information collected by the sensors is quickly growing. However, merely collecting a large amount of data is not enough; we need to interpret and act upon the data in a holistic manner. The information containing the captured context needs to be effectively transferred into centers of calculations, where all the local data are merged; creating an overall sense of the context that is interpreted. Supporting this desituation of context seems to be of crucial concern for ubiquitous computing, and in the next section, we will explore this empirically in the use of RDS.

RESEARCH METHOD

Research Approach

As this study seeks to explore the desituation of context in maintenance work, organizations with experience of RDS were selected as objects of study. The research data were collected in six different organizations. The companies are MacGregor Cranes (MGC), Monitoring Control Centre (MCC), PowerDrive, Alpha, Beta and Gamma (fictitious names on the last four), all located in Sweden. The selection of the sites had theoretical rather than statistical reasons (Yin, 1989), as the primary aim is to understand more than it is to generalize. The results might thus not be generalizable, but this does not exclude the possibility that they can contribute to the collective body of knowledge of a discipline (Kautz & McMaster, 1994). The selection of the sites was based on their willingness to cooperate, the availability of multiple sources and the possibility of purposeful sampling (Peppard, 2001; Yin, 1989).

Table 2 presents an overview of the case organizations and their relation to the RDS. Further details of the organizations are presented. The study employed a qualitative data collection technique using semi-structured interviews. In all, the study includes 31 interviews, conducted by two researchers of which one is the first author of this paper. Four interviews were conducted at MGC, four at PowerDrive, seven at MCC, five at Alpha, six at Beta and five at Gamma. The interviews lasted between 45 minutes and 3 hours, with an average of about 60 minutes. Each interview was audio taped, which allowed the researchers to focus upon the respondent and formulate follow-up questions. The interviews were transcribed to enhance the analysis. All interviews were conducted on-site at the respondents' workplace, which allowed the researchers to gain some insight into the work context. When choosing participants, we wished to include individuals with different relationships to the technology. No restrictions in participation were imposed from management, and a contact person at each company helped us choosing respondents for the interviews. At all organizations respondents were chosen to cover both individuals in a managerial position and people working with equipments equipped with the RDS.

The data collection covered questions related to sensory data collection, data transfer and respondents' view of this process, issues of value, and the benefits and challenges of using this technology. Depending on the respondent's experiences, follow-up questions were formulated during the interview.

The results of this study were developed in a three-stage analysis. During stage one, the transcription from each interview was read through. While reading, notes were taken to summarize the material. Stage two involved a cross-analysis of the interviews to find similarities and differences. Each interview gave an explanation of the case from a certain perspective; for example, a technician's view could be compared with a manager's view of the technology. This crosschecking of different perspectives ensures validity, as the case interpretation is built up from multiple sources. The empirical investigation is based on the two processes of capturing and transferring context, which together constitute the desituation of context. The third stage of the analysis included a cross-case analysis, searching for similarities and differences between the cases regarding the processes of capturing and transferring context. ANT was used as a lens to make sense of the empirical findings as a theoretical abstraction by challenging or generalizing concepts (Walsham, 1997).

The Case Organizations

MGC is a manufacturer of cranes and has recently developed a first prototype of a RDS. Sensors are installed into the crane to collect data about its condition. These data are sent to a server at MGC every time the crane is turned off, where they are analyzed to find out when maintenance is needed. As the cranes travel around the world, they are also equipped with a Global Positioning System that shows where the cranes are at the moment. This position is sent to MGC every six hours and is valuable when scheduling the maintenance.

PowerDrive is a manufacturer of motors that also has developed a RDS for enhancing preventive maintenance. Their system is also based on sensors embedded into the equipment that collect data about its condition. Data are collected every 30 seconds and are temporally stored in the system before they are transferred to a server at PowerDrive for analyses, once every day. If something is detected, an alarm is

Table 2. The organizations in the study

Organization	***Activity***
MGC	Manufacturer of shipboard cranes, RDS provider
PowerDrive	Manufacturers of motors, RDS provider
MCC	RDS provider
Alpha Customer to PowerDrive and MCC	Mining industry company, RDS user
Beta Customer to PowerDrive	Processing industry company, RDS user
Gamma	OEM to processing industry, RDS provider

automatically sent out to technicians via SMS or e-mail with information about the problem. A report that summarizes the equipment's condition and detected problems is also compiled every month and sent to the customer.

MCC is a provider of preventive maintenance services based on RDS. Unlike MGC and PowerDrive, they are not manufacturers and do not develop RDS on their own, but participate in such projects with other companies. MCC take responsibility for implementing the RDS into the customers' equipments, and they also take responsibility for analyzing the collected data and informing the customers when maintenance is needed.

Gamma is a supplier of installations for the processing industry. These installations include equipment produced by PowerDrive. Gamma has developed a RDS for its installations, but it does not measure any specific parameters of the motor. The customer can choose to use both a RDS from Gamma and from PowerDrive, as these two systems complement each other. Like the other manufacturers, Gamma also has a group of technicians specialized in analyzing data collected in remote systems. The last two organizations, Alpha and Beta, have RDS installed at their plants.

All companies have experience of either developing or using RDS, which gives a rich view of remote diagnostics and issues associated with such applications from both a local customer perspective and a remote supplier perspective.

DESITUATING CONTEXT

In this section, the desituation of context is explored empirically based on the results from the case study. In the desituation of context, two different processes take place. First, context is captured and second, transferred to another setting. In RDS, context is captured via sensors, and the data contain information about a equipment's condition, identity, time and, if the equipment is mobile, its position. These data are then transferred to a remote centers with technicians specialized in analyzing this type of data. To understand the desituation of context and how it can be managed, this section will explore these two processes - capturing context and transferring it - in the industrial setting.

Capturing Context

The equipment's physical condition is transformed into a representation (an immutable mobile), by the sensors, which record information without a technician physically visiting the equipment. The data collection is viewed primarily as creating a stable and regular flow of data, whereas manual collection could result in corrupt data due to irregularities in time and variation in the use of measurement instruments. A developer of RDS at Gamma explains:

Manual measuring is not acceptable. People are not good at repeatable accuracy. You don't use [the instrument] in the same way each time, you don't hold it in the same way and you are not able to place the measuring circuit in the same position each time. What people are good at are analyses.

According to this developer, the stability of the data is enhanced with automatic data collection. The developer argues that the collection is more reliable with sensors, as the measuring technique always remains the same, which enhances the quality of the data. Moreover, the sensors expand human sensing, as they can monitor things that humans cannot and in places where humans cannot go. For example, a sensor can pick up sounds that the human ear cannot recognize. In the processing industry, there are many safety regulations, and with fewer people present on the floor, the risk of accidents decreases. When the equipments are running, it is sometimes impossible for humans to get access to them and measure parameters. Sensors thus create possibilities for a stable and safe data collection. The digital sensor technology also transforms the equipment's condition into a mobile state, where it can be transferred via network connections to remote sites.

An uncertainty observed among the organizations in this study regarding the data collection is the potential for faulty sensors. Abnormal data can be caused either by problems with the sensor or by real problems in the equipment. If faulty sensors cause them and this is not detected, this will lead to misinterpretations of the equipment's condition. The organizations try to avoid these problems through regular calibrations of the sensors. The technicians can sometimes detect problems with the sensors by their experience of what values are normal and what are not. If the measured values are substantially deviant, technicians begin to suspect problems with the technological equipment.

When equipment is to be monitored, a number of parameters have to be chosen. During the development process at MGC, the technicians had a long list of parameters they wished to gain access to. During the process, this list was reduced both due to technical reasons (no sensors were available that could collect the parameter) and due to costs (some sensors were too expensive relative to the overall value of the system). Picking out the relevant parameters is crucial for condition-based maintenance, as overlooked parameters may be the ones causing an unplanned break. The providers in this study show a tendency to wish for a constant increase in the number of parameters being collected. Even the customers experience the growing data collection; the director of maintenance at Alpha says:

We do measure parameters that we don't get any benefit of. But if you haven't measured them, the data are lost.

By collecting more and more data, the companies want to build an all-embracing model of the equipments to perform better analysis and to detect abnormal conditions and trends. Collecting more data can also be a strategy to minimize the uncertainty of incorrect sensors. If many parameters are captured, values can be crosschecked when uncertainties arise. However, even though increased data collection can minimize uncertainties and give more information about the equipments, all organizations stress the risk of information overload. The amount of data is growing fast, often faster than these organizations are able to analyze them.

Transferring Context

After the sensors have captured the data, this information is transferred to remote centers for analysis. When the equipment is mobile, wireless connections are used for the transfer. In this study, the remote centers are located within the suppliers' organizations. At these centers, specially trained technicians work with analyzing the collected data and compare them with previous measurements. Through this analysis, the technician can detect abnormal variations and, hopefully, prevent breakdowns. To companies offering services based on the collection and analysis of data, the technology allows for a seamless service solution, as the technology is always present and enables context to be transferred to remote sites. To the suppliers, this presence creates opportunities for new types of services. MCC, for example, has their technicians in the northern part of Sweden but envisions becoming a global service provider of remote diagnostics solutions without opening new offices at new locations. MGC also highlights the time and space independence in promoting their RDS. In their brochures, they say:

Wherever you are— we are there…we provide seamless service solutions…we monitor the condition and performance of your cargo handling equipment, wherever the ship is in the world.

MGC's presence at customer sites is, of course, via the RDS by which it monitors the shipboard crane at a distance. PowerDrive also offers a RDS, where data are collected from equipments all around the world and then transferred to the company's main office, where analysis takes place.

Transfer of data from many dispersed objects into one place enhances the possibility of comparing data, and the technicians performing the analyses gain experience from many different equipments and settings. The remote centers act as centers of calculation, collecting large amounts of data about objects in the periphery. To the manufacturer, this possibility creates new business opportunities in the after-sale market while at the same time giving it important feedback about its equipments. With the remote diagnostics of equipments, the manufacturer gets a better picture of how its equipments work in actual settings and whether or not common problems exist within equipment runs. PowerDrive, for example, has been using its system to test equipments before they are launched, which has been valuable in equipment development, as it gives an overall picture about the performance of certain equipment categories.

The companies in this study highlight that even though the equipments are constantly monitored with RDS, only data about a specified number of parameters can be collected. Thus, the picture a remote technician gets is not "complete." As the director at MCC expresses it,

When you physically walk around in the plant, you get a lot of other signals; you see, hear, and feel.

The diagnoses that can be performed with the system are limited to the number of parameters that are monitored. A physical walk-around by an experienced technician who can see, hear, and feel when something is abnormal can detect things that the technology and the remote technician cannot. A hydraulics technician at Beta also notes:

You have to learn to know the equipments individually. You don't do that remotely.

This highlights a limitation with the RDS compared to an experienced technician walking around in the plant. Although the system can detect conditions by detailed analysis that the local technician cannot, many of the respondents point out the importance of keeping in mind that the limitation of the collected data. The hydraulic technician at Beta expresses both a risk and a limitation of the technology:

With more monitoring, you can work more and more online and less people will be out among the equipments. You won't get the same feeling for the equipments. The only things you see are, for example, temperature, pressure, and flow. You don't know how it sounds.

The RDS and the remote technicians are limited to the data collected by the sensors. At Beta, they gave an example of problems with a motor due to poor oil quality – a parameter that the RDS did not monitor. Another example is given by an technician at Alpha, who described how the company installed a RDS at one of the oil pumps that monitored the oil level. The system was supposed to be a complement to the operators' traditional regular walk rounds in the plant. When the oil level sank, an technician located in another building called the operator and instructed him to fill it with more oil. After a while, the operator got accustomed to the phone calls and stopped walking around in the plant. One day the equipment almost broke down due to other problems that the system did not detect, but the operator would have seen it had he walked by the equipment. To him, the phone calls from the remote center had become a work practice that would indicate all possible problems with the equipment. As a result, he viewed the walk rounds as unnecessary.

The example highlights the constraint of transferring context to another setting; the depiction of the reality is limited, and not all problems can be detected. However, the example also gives insight into another potential constraint to the possibility of transferring context. The RDS can create a remote closeness where the remote technicians can get "close" to the equipment, and at the same time, create a local distance at the plant, which is what happened at Alpha. The operator stopped physically walking by the equipment, as he relied on the RDS and the new procedure of getting an alarm when something had to be done. The example highlights the potential loss when the local operator or technician is not instituted in the new work practices, which creates a local physical distance between him and the equipment.

With the use of RDS follows the critical issue of managing both the benefits and the limitations of capturing and transferring context. Not only must the remote centers be well functioning, the local technicians must also be incorporated into the maintenance work; otherwise, they may be pushed into the periphery. The director at MCC expresses it as such:

When the company buys services from the remote group, the local group seems to view the remote group as responsible for everything, at the same time as the remote group views the local group as responsible for basic monitoring and walk rounds. This happens when the borders are not clear; the responsibility has to be clearly expressed.

The "remote closeness" came as a result of the use of RDS and the possibility of transferring context. The "local physical distance" came as a result of the local groups assessing walk-arounds as unnecessary and shifting responsibility. The local groups seem to interpret the RDS as a replacement of the old work routines, although they are aware of the technology's limitations.

DISCUSSION

With RDS, contextual data is desituated – that is, captured and transferred to another setting. Managing the desituation of context is thus of crucial concern in ubiquitous computing environments. In this paper we aspired to identify strategies for how to deal with the desituation of context in ubiquitous technology use through a case study of six different organizations either developing or using RDS. In what follows we identify two main strategies for accomplishing this: creating a center of calculation and bridging the gap between the physical world and the digital world.

Creating a Center of Calculation

With RDS, maintenance work faces new ways of organizing and working, and different modes of ordering extended through people in order to include technologies and organizational arrangements. Acting based upon the interpretation of automatically collected data is a challenging task in an environment used to basing actions on physical presence and manual skills. Grudin (2001) argues that learning to work in a world of context-aware applications is one of the greatest challenges that we face today. Through the use of RDS, data about equipments can be automatically captured and transferred to remote settings, which is a process whose management becomes crucial. A strategy for dealing with the desituation of context has to take into consideration how to organize and deal with the data flow that emerges. In the case of RDS, the technicians at the remote centers serve as key actors in the process of handling the data flow and analysis.

With the remote technology, data are automatically captured with sensors, transferred via a digital network, and combined in the centers of calculation where they provide the technicians with data about the equipments' performance and condition. When data are transferred from the local setting to these centers of calculation, the context is desituated. The transformation of the equipment's condition into digital numbers makes it possible to compare different equipments with their ideal condition and with each other, independent of their physical location. At the centers, a crucial activity is to create an overall picture of the equipment's status that can be analyzed without losing the specifics of the local contexts. The overall picture will make it easier to analyze the equipment's condition and perform timely maintenance. To successfully manage the desituation of context– we need these centers of calculation as a place in which the captured local contexts meet.

To enable the creation of centers of calculation, data must be transferable and still remain the same i.e. an immutable mobile. The digital network makes data perfectly mobile by making it possible to transfer them thousands of kilometers in milliseconds. It is also possible to combine binary data; data can be received from different sources, combined and compared with other data sources. The data collected by the RDS have in this study shown a degree of immutability in their character, as they can be captured and transferred to the centers of calculation. Concerning the stability of the data, uncertainty can arise due to the potential of incorrect sensors. It is thus the capturing of context that is perceived as being more uncertain than the transportation process. The three characters of the immutable mobile - mobility, stability, and combinability - seem to be characteristics important for RDS and essential to the creation of centers of calculation.

Bridging the Gap between the Physical World and the Digital World

To the technicians at the remote centers, the equipments are represented digitally via the captured parameters. As this study has shown, such inscription, a digital representation, gives the technicians a remote closeness to the equipments, as they can constantly monitor its condition and performance, independent of the physical distance. RDS does thereby decrease the gap between the world of information and the physical world, as the local contexts are desituated to the remote centers. However, in this study, this process showed to be a struggle between information gain and information loss, which retains the gap between the two worlds. The created remote closeness was accompanied with local physical distance where the local technician quit the walk-rounds and relied on the RDS. This require the organization to use different modes of ordering (Law, 1994) extended through people to include technologies and organizational arrangements to make the local technician instituted in the new work practices. A sense of locality is lost when specified data are collected and transferred via the digital network to a remote place, which creates a limited view of the monitored context. Context that is not captured is totally invisible to the remote technician. The second strategy to pursue when context are desituated is thus to find ways of bridging the gap between the physical world and the world of information.

To compensate for this gap, organizations engage in increased data collection, even though they cannot fully be used in the analyses. However, digitally represented contexts will always be different, as the captured context is by default moved from its context. The process of desituating context will always imply a process of abstraction, as the sensors will never capture a full context. All abstractions are limited, but they have another value; they can be represented and made mobile across time and space. The process of abstraction and a limited picture will thus be permanent in desituating context, and it is the process of abstraction that enables data containing contextual information to become an immutable mobile and transferred to the remote centers.

New data will always be available through sophisticated sensor technology in RDS. Therefore, it is a challenge to resist engaging in collecting more and more data. Constantly adding new sensors to capture additional context leads to an escalation of the amount of data that needs to be compiled, but the picture will still be limited. Capturing context digitally is also associated with certain costs. While some data are expensive to capture, other data are easier to collect. With RDS, these costs must be balanced with the benefits in terms of possibly preventing the breakdown of equipment. Increased data collection also raises questions about privacy, accuracy and interpretation (Grudin, 2001) which stresses the importance of balancing the data collection process and not letting it escalate beyond control.

According to Fleisch (2002) sensor technologies make the digital and the physical world approach each other and slowly merge together. However, even though the digital world includes more and more data, the remote picture available to the technicians is limited. A physical visit to the equipments gives maintenance workers information through all of the senses. This is lost when the equipment is diagnosed remotely via a specified number of parameters, as the sensors only detect what they are designed to. One should, however, bear in mind that sensors can observe things that the maintenance workers cannot and in places where they cannot go. Nevertheless, a sense of locality is lost when specified data are collected and transferred away via the digital network to a remote place. In this study, both the local maintenance groups and the remote groups were aware of both their own and the other group's benefits and limitations. The remote groups knew they were not able to diagnose the equipment at full capacity, and the local groups knew that they were not able to predict the condition of the equipments with the same precision as the RDS. Although both parties were aware of the limitations in their own work, some of the providers emphasize the risk of putting the local technicians in periphery when the RDS is installed. Neglected maintenance from the local group could result in an overall unsuccessful maintenance strategy, as these two groups complement rather than replace each other. Decisions based on analyses of the digital world must thus be combined with insights from the physical world; otherwise, critical information can be lost. The separation of technicians and equipments demands a compensating network of practice, which in this case is the practice of the local technicians. It is thus important to find ways of combining these two groups of actors, modes of ordering these organizational arrangements (Law, 1994). Together these two groups and the technology constitute a collective of humans and non-humans (Latour, 2000), a hybrid collectif (Callon & Law, 1995). This maintenance network is growing, as each member as well as the network as a whole learn and improve their performance in relation to remote diagnostics. Managing the implementation of RDS and the gap between the remote and the local contexts can then be seen as the cultivation of such a collective. The local practices on the field must be reconfigured and instituted in the collective for RDS to become safe and workable. RDS thus makes it necessary for the local practices to change and adapt and for the remote centers to ensure that they are instituted in the collective. Only then can the benefits of the RDS be reached.

CONCLUSION

In this paper we have seen how the desituation of context is of crucial concern in ubiquitous computing environments. With the aim of identifying strategies of dealing with the desituation of context, we have explored how the process of desituating context is managed in organizations using RDS.

RDS goes beyond the current context-aware ubiquitous applications focusing on identity and location of users through its use of identity, location, status and time to diagnose the condition of equipment. The results reveal that capturing and transferring context - desituating context - is an important issue to address in ubiquitous computing. To manage this process, organizations need to find strategies of creating and managing the center of calculations, which serves an important role in the process of remote diagnostics. Moreover, they need a strategy of bridging the gap between the digital and the physical world created by this new way of organizing the maintenance process.

The creation and management of centers of calculation involve setting up a global site where captured contexts meet and merge into a remote setting. To enable long-distance control, all data must be compiled into one manageable view without losing the specifics of the local contexts. Data collection must thereby be designed with this in mind. To bridge the gap between the digital and the physical world, a new kind of maintenance network must be formed, one in which local technicians' practices are reconfigured and instituted.

The findings of this study challenge the existing assumptions of ubiquitous computing. While context awareness in relation to people will draw our attention to issues such as context switching as users move between different locations, context awareness in relation to things allow for a ubiquitous information environment with local contexts meeting in a global setting.

Managing ubiquitous information environments thus also involves managing the desituation of context. By appreciating this, and by appreciating the challenges that arises when contexts are desituated in relation to RDS use, adopters of the technology stand a good chance of realizing the benefits of ubiquitous information environments.

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