# Context of Use in Mobile Support Systems for Maintenance Work

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## ABSTRACT

In this paper, we describe how the contexts in which maintenance work takes place lead to different technical requirements in the design of mobile systems. Conceptual solutions for context-oriented design which are derived from user participation are discussed.

## Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – user-centered design, interaction styles, input devices and strategies

## General Terms

Design, Human Factors

## Keywords

Mobile devices, maintenance work, human-computer interaction, usability test, requirements specification, non-linear browsing, audio-graphic interfaces, contextual inquiry, knowledge management

## 1. INTRODUCTION

During the product life cycle an instant access to all product-related data and information is crucial. This aspect is especially important for maintenance purposes (e. g., of wind energy plants). It does not only reduce cost-intensive mistakes but also additional work and expenses caused by call backs, interruption of work or reduced performance of the plant. To assure a high availability of data and information apart from the company or service station the mobile access is indispensable. However, not only the necessary data is of high significance but also the *context of use* has to be considered carefully. Moreover, the right choice of a mobile device depends on the context of use and its related processes. Thus it is important to clarify the purpose of an application. But this does not only demand for gathering of information and data which has to be shown but also the amount of data which occurs during the whole work process. Therefore, for instance handhelds with stylus input or mobile phones are appropriate to access information, but they are critical in the field of high data density.

Another significant aspect is the representational and computational limitations of mobile devices. Depending on the chosen device a clear structure of how the data is shown has to be elaborated.

This paper describes the relevance of the context of use while applying mobile devices to maintenance work. We want to focus on concrete concepts and present use cases where the context of use is highly important. The implementation of our findings is in progress right now.

## 2. CONTEXT OF USE IN MAINTENANCE PROCESSES

During maintenance work it is important that the technician can concentrate on his work tasks. Thus external processes and tasks (e. g., connecting cables) have to be in focus, while internal tasks (e. g., entering data into the mobile device) are secondarily. Due to the fact that the visual attention of the user is focussed on external tasks, perils are prevented and it is assured that the primary objective (e. g., observation or controlling) is not unattended.

Due to the fact, that parts of the equipment have been substituted or are not available anymore, other spare parts have to be installed. In most cases these changes are not well documented. Either they are not detailed enough or only in the object (e. g., switch cabinet) available. Updating these changes immediately throughout all instances prevents massive object-related differences, because the divergence between “as-designed” and “as-maintained” does not exist anymore. Therefore a regular actualisation of object-related data is of high importance. The ascription of changed hardware, for instance if the exchange of a electronic assembly group requires additional modification of the system, has to be gathered by the system, registered and if appropriate added with additional annotations, which describe the reason of the modification.

Having the right spare parts at hand is besides the necessary information material indispensable. The maintenance worker has to know which parts he needs for his work tasks. It is very unproductive if he realizes on location that he does not have the right parts with him, because someone has changed the construction without reporting this change.

Furthermore, knowing if a specific part is in stock can also optimize the maintenance process. Taking parts from the stock has to be recognized by the system to ensure that parts which are currently not in stock can be re-ordered immediately. Thus an effective and efficient spare part management system can be provided. In addition a very important issue which spare part management system has to fulfil is the management of data in regard of the serial numbers of the spare parts instead of object-specific parts. Ensuring this kind of management enables a transparent acquisition of material movements. Storing the spare parts according to their serial numbers also empowers the "as-maintained" status of each object and ensures that only spare parts with the correct version numbers are used for repair purposes.

**Table 1: Contexts of Use in Wind Energy Plant Maintenance**

| Users | Tasks |
|---|---|
| Dispatcher | Planning maintenance orders<br>Controlling maintenance work |
| Maintenance worker | Inspection<br>Preventive maintenance<br>Repair work |
| Engineer | Design<br>Re-Design |
| Customer | View status of equipment |

As shown, there is a huge variety of problems and contexts that occur in maintenance processes. Nevertheless all of them require intelligent ways of how to represent necessary information, especially on mobile devices.

# 3. USABILITY TESTING: FROM DESKTOP TO MOBILE DEVICES

Considering the context of use at a remote workplace also demands – besides dealing with information architecture, knowledge management and intelligent filtering – for an elaborated approach in usability engineering and testing. Whereas desktop usability testing is mostly standardized, the testing of mobile devices still is a huge challenge due to their physical characteristics. For instance, handheld devices, since they are small and mobile, require special observation and testing strategies, which cannot be achieved by traditional evaluation and testing methodologies. Within traditional desktop usability testing recording all needed information without disturbing or influencing the test candidate's behaviour and acting is quite easy. Testing mobile devices instead poses a unique challenge because traditional usability testing takes place in office-like environments – because this is the location where work takes place. On the other hand, the testing situation and environment for mobile devices normally is totally different, for instance while working outside the influence of the context variables is quite dominant.

As Mason [7] points out, the purpose of usability research must provide both, the richness of detail (corresponds to relevance) as well as a certain tightness of control (corresponds to rigor). According to the different approaches of usability testing methodologies, Lindroth et. al. [6] evaluated the usability testing methods and theories from a mobile perspective. They found that traditional usability testing methods do not consider the context of use. The result of those tests is the measurement of how well the device can be used in an office-like environment. Their methodological conclusion for the problem is not to develop totally new methods from the scratch but to use a combination of different methods, to achieve both, rigour and relevance.

According to this, evaluating the usability of mobile devices requires different approaches instead of a one-dimensional formal lab testing. However each test of a special device type requires a different natural testing environment – associated with the special context of use, for instance on the one side laptops will not be used while walking, but on the other side PDAs or mobile phones are often used exactly in that situation.

Whereas the usability testing of hardware devices or prototypes is different between desktop and handheld systems, usability testing of rapid prototypes – whether they are constructed from paper or on-screen – is very comparable for desktop software and handheld devices, because the settings as well as the methodologies are the same. Thus the question which usability testing method can be used for evaluating mobile devices depends on whether the complete hardware device, only some design concepts, or only the interface has to be tested.

There are several methods for testing the usability, which can be divided into the following three categories: a) inspection and evaluation, b) testing, and c) inquiry. From our point of view the context of use has to be analysed by a usability context analysis (see [9]), ethnographic field study or contextual inquiry (see next paragraph). Furthermore we suggest to evaluate the usability of mobile devices also by using the thinking-aloud protocol – or even better the constructive interaction method – to understand how respondents view the system in combination with performance measurement, to see whether the respondents succeed or fail in performing a task (along with task completion times and error rates). Additionally a proactive field study can be conducted to understand the target audience and their needs.

# 4. CONTEXT-ORIENTED REQUIREMENTS SPECIFICATION

As seen, in the case of mobile systems consideration of context is even more important than in desktop applications because mobility by definition leads to different usage situations concerning location, task, physical environment etc. Therefore methods have to be developed which allow analysing and designing mobile devices from a contextual point of view. Weis formulates it like this: "The differences between desktop computers and handheld devices require different design strategies. Handheld devices, with their increased mobility, limited memory and processing power, and small display sizes offer unique challenges – and opportunities – for design." [10]

## 4.1 Contextual Inquiry for Mobile Systems

Concerning mobile systems we have to apply methods which go far beyond a "linear analysis" of separated tasks and technical devices. The literature about the application of ethnographic approaches in computer science shows several methods focussed on context analysis. One of the most prominent methods is *contextual inquiry* introduced by Karen Holtzblatt and Hugh Beyer in the beginning of the nineties [4]. Contextual inquiry is a field study method where the process of use is observed by usability specialists in daily work situations. Collecting concrete data is accompanied by a dialogue between the user and the

observer to clarify special situations. The observer uses a number of focus topics to guide the dialogue. The method respects the user as partner and expert of his field of activity.

By conducting a contextual inquiry we tried to find out which data is needed at the workplace. Therefore it was important to understand the work processes, company structure and IT requirements as well as the personal abilities of the employees. Moreover it has to be clarified which task has to be accomplished during the product life cycle as well as which kind of data and information is needed and will be generated. Objective of this analysis is a categorisation of the data and information according to their importance and occurrence/frequency. To provide data in the context of use it is also important to analyse in which stages of the product life cycle the data and information is needed.

## 4.2 Remote Contextual Inquiry

To gather results of as many cases as possible we consider developing the method further to become a remote analysis tool (cf. also [2]). We already experimented with remote analysis methods and tools by using standard software (Morae from TechSmith) which is able to capture the screen of the user device, to record the user's expression (video/audio), to mark special unclear situations by time stamps and to integrate all the information into one single video film for later discussion with the user (video confrontation). This technology will be applied by us to mobile devices. Because of limited capacities of the mobile device (memory, processor) the recording process has to be shifted to a second computer which is connected to the mobile device via wireless technology. We will evaluate the method of remote contextual inquiry carefully dealing especially with the problem that the original social character of the method is partly removed.

# 5. THE M-PDM PROJECT AS AN EXAMPLE OF USE

Due to the fact, that most of the tasks of maintenance workers are based on complex coherences and regarding the fact that the objects have a complex structure, it is obvious that the maintenance person has to be supported by powerful tools and devices. The goal of our project "M-PDM: Mobile Product Data Management" is the development of a mobile solution to assist maintenance workers to accomplish their daily tasks more effectively and efficiently.[1]

Maintenance work in wind energy industry is a distributed work taking place in various locations outside the factory. Working in narrow spaces and under difficult conditions at the top of a wind mill asks for special solutions concerning the applied mobile technology.

[1] The project is performed together with partners from industry: CONTACT Software GmbH, Bremen (Germany), has developed a product data management system called "Common Information Model Database (CIM Database)" which is used by wind energy plant producers like ENERCON or energy producers and distributors like EWE. This system will be the kernel of the mobile application. In a further step CIM database will be optimized for mobile use. CONTACT develops the base technology; the Center for Computing Technologies (TZI) is responsible for the requirements specification, development and testing of scenarios as well as usability testing.

*Work context: Hardware.* The physical attributes of the chosen mobile devices do also rely on context. The different working environments have different demands concerning the device. For instance, large and clean rooms with several contact surfaces provide space for the usage of laptops and other larger mobile devices, whereas small and dirty rooms only allow the usage of wearable systems with either a head-mounted display or no visual output (speech is used for in- and output). Also the kind of work which has to be accomplished plays a significant role for the choice of the right hardware. If the maintenance worker has dirty fingers (e. g., caused by oil), it is not advisable to use a device with a touch-screen or even a keyboard. Due to the fact that mobile devices such as handhelds are limited in their computational and representational characteristics, it is necessary to concentrate on the in- and output methods. Appropriate forms of representing and filtering the necessary data have to be developed.

During maintenance work it is important that the technician can concentrate on his work tasks. Thus processes and tasks concerning the plant installation or repair (e. g., connecting cables) have to be in focus, while internal tasks (e. g., entering data into the mobile device) are secondarily. Furthermore, some work tasks demand fully attention from the user, which the hardware – but also the software – has to provide. In this case it is advisable to use alternative input and output methods such as speech. Due to the fact that the visual attention of the user is focussed on external tasks, mistakes and dangerous situations can be prevented and it is assured that the primary objective (e. g., observation, measuring or controlling) is not neglected. Nevertheless, this kind of input can only be used if the context of the environment is appropriate, for instance noisy environments do not allow any voice recognition.

Alternatively to electronic devices (e. g., tablet computers), traditional paper and pencil could be simulated by "electronic paper" and "smart pen" technology.

**Figure 1. Head mounted display**

Another very important issue is the fact that the maintenance worker might have to have his hands free (e. g., during measurements). In this case the usage of wearable computing devices is advisable. In combination with a head-mounted display, the maintenance worker can use both hands for his work, while taking a look at certain instructions. In accordance to this, the system must not constrain the user while performing his work task. Thus the mobility of the system is of high importance, because the user has to be flexible and agile during his work.

*Work context: Software.* But not only the hardware is affected by the different contexts, also the software has to fulfil contextual demands. Furthermore, the software is also influenced by the chosen hardware device and its computational and representational characteristics. Working with mobile devices demands

intelligent data filtering due to their physical constraints. This kind of filtering affects both, the gathering and categorization of input and output data according to their importance, occurrence and frequency. Depending on the device the data and represented information has to be filtered and only the information which is needed for the current work task has to be shown. Another approach to represent data is to use a zooming method which displays the most important or relevant information first, and then the surrounding area (focus-oriented image improvement). This method is very useful for showing construction drawings or other large plans with an initial focus on a special spot. If on the other hand the worker has no special idea where to find some given information it might be useful to browse in a non-linear way through the document (cf. methods of hyperbolic browsing). In other cases, it is more advisable to have the ability to chose or preset the information one currently needs or by using drill-down methods to get to the desired information. Limited space lead to the idea to differ between more important and less important information: Using our various perceptional channels can result in the design of a hybrid device, where important information is presented visually whereas less important information is provided by (more transient) audio. Combining audio and visual perception can also be used to implement and evaluate "audio-graphic" navigation interfaces.

To provide data in the context of use, it is also advisable to analyse in which stages of the workflow or even of the product life cycle certain data and information is needed. According to the filtering of data the aspect of synchronizing or replicating the data onto the mobile device or vice versa plays an important role. If only a certain amount of the object-related data is needed, it is not advisable to transfer all data which belongs to the complete object or system.

*Knowledge: Co-operative use in context.* The maintenance process does not only demand physical and technical skills from maintenance workers but also requires a lot of knowledge about the system structure and behaviour, material characteristics or composition details. Therefore, a "knowledge flow" will be organised among maintenance workers. They will deliver knowledge to the system and at the same time profit from the knowledge of other workers, already store in the system. Knowledge exchange and co-operative use of knowledge can be moderated and organised by using "open-editing" approaches, like the Wiki systems. Again, this special context – the co-operative knowledge approach – leads to specific technical solutions: a. annotation mechanisms like virtual post-its or voice annotations will be provided for easy knowledge delivery; b. various information retrieval mechanisms, e.g. associative search, similarity search and the application of ontologies will be evaluated as well as the usage of semantic web technology.

One of the most challenging tasks in the research and development project described is the careful selection of appropriate technology which fits precisely into the work context on the one side, and the necessary integration of all the contextual components mentioned above into a unified system with a high degree of usability on the other hand.

Trying to support workers by adjusting the amount of information which is provided to the end user must not result in "feature overkill" in the end.

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