Nomadische und “Wearable”-Benutzungsschnittstellen: Entwurfs- und Evaluationsprinzipien für zukünftige Anwendungen

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Editorial

Der Workshop “nomadische und Wearable-Benutzungsschnittstellen” ist die erste Veranstaltung des Arbeitskreises Wearable und Nomadic Computing des Fachbereichs Mensch-Computer-Interaktion der Gesellschaft für Informatik. Die Zielsetzung des Arbeitskreises ist es, die Anwendung von unterstützenden, mobilen Computersystemen zu untersuchen und zu fördern, insbesondere Anwendungen im professionellen Umfeld, aber auch mobile Kommunikations-, Lern- und Entertainmentsysteme.

Ein primäres Ziel dieses Arbeitskreises ist die Professionalisierung des Entwurfs von tragbaren Computersystemen und deren Benutzungsschnittstellen, insbesondere im Hinblick auf die Marktfähigkeit der Technologie sowie auf die Akzeptanz der Lösungen. Daher freut es uns als Veranstalter besonders, daß zahlreiche Einreichungen aus dem Bereich der Industrie und der industrienahen Forschung kommen.

Die Auswahl der Publikationen erfolgte mit dem Ziel, universitäre Forschung und industrielle Anwender zusammenzubringen und dadurch den aktuellen Forschungsstand und die Bedürfnisse der Anwender zu dokumentieren. Der Schwerpunkt des Workshops “Entwurfs- und Evaluationsprinzipien für zukünftige Anwendungen” dient dabei insbesondere dazu, die Umsetzung von Anwendungen auf der Basis von Forschungsergebnissen zu optimieren und daraus eine “Best-Practice”-Sammlung zusammenzustellen.

Die Herausgeber danken allen Einreichern, Gutachtern und Helfern, insbesondere auch den Organisatoren der Mensch und Computer 2007 und Professor Oberquelle vom Fachbereich Mensch-Computer-Interaktion für die Unterstützung beim Aufbau des Arbeitskreises.

Holger Kenn, Hendrik Witt

Vorwort

Wearable and nomadic computing requires a new working paradigm: Complex tasks are supported with a minimum of active human-machine interaction. Instead of working at the computer the user is supported in primary tasks (e.g. maintaining a mechanical part) by the computer in an ambient way. Mobile professionals keep their attention focused on the work environment supported by valuable information provided by this new type of solutions. The break-through of wearable and nomadic computing is still missing; only a few solutions are an economic success. As the way of working is drastically affected the user acceptance is a key issue. With the actually worldwide largest project in the domain the EC funded wearIT@work (`www.wearitatwork.com`). In the four application domains of healthcare, production, maintenance and emergency response most important sectors of Europe's economy are addressed.

Wearable and nomadic computing is for Europe with its high labour costs a chance as productivity and quality of life are increased by unobtrusive information provisioning solutions. Furthermore this technology opens up new business for technology providers, systems integrators and consultants. With the project SiWear the German Ministry of commerce just launched a further project in this domain for the automotive industry (`www.siwear.de`)

This working group was established to foster the successful research activities in the domain and cluster the German experts in the field.

I wish the working group a successful start.

Professor Michael Lawo, Universität Bremen

Mobile Navigation and Augmentation utilizing Real-World Text

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Abstract

Mobile, smart devices are already available in everyday life. Most of them offer a rich feature set, including camera, GPS antenna, or even WIFI modules. Navigation software utilizing GPS to acquire location data became very popular on these mobile clients. However, due to hardware restrictions GPS positioning cannot be used for indoor scenarios. In contrast, this paper is focused on navigation for indoor environments targeting on a low-cost solution, without the requirement of additional hardware installations or markers inside buildings. A server-based optical character recognition service is used to map images containing unique text passages – acquired with a mobile client – to additional meta data, e.g. locations or orientation. We also show that augmented-reality methods can be used to provide an intuitive presentation and interaction system by overlying real-world images with additional information like navigation symbols or internet hyperlinks.

1 Introduction

Many applications are designed for mobile devices like PDAs, Smartphones, or Ultra Mobile PCs, however, navigation is still one of the most popular software used on these appliances. Commercial applications to support users in path finding for outdoor scenarios are already widely available. In contrast, systems that help users to find locations inside buildings – i.e. meeting points, rooms, persons, etc. – are not yet common and most of the available solutions require additional hardware setups inside the target environment, as the GPS signal cannot be received inside buildings. These installations range from low-cost visual markers (1D/2D barcodes) up to expensive ultrasonic or electro-magnetic beacons that have to be deployed inside the building at suitable positions, i.e. good visible locations for optical markers. Both cases require an involvement of the facility management to evaluate either if a high number of visual markers can be placed inside the building or a costly installation of beacons is possible.

In contrast, the system we propose makes use of commonly installed good-recognizable features at visible locations: Text phrases of, e.g., door plates, posters, or labeled installations are used to indirectly identify the user's current location. A database of mappings for text paragraphs to additional meta data, most importantly the location inside the building, is used in combination with a server-based OCR system. This service is used by the developed client software running on a PDA and allows users to capture images of text inside the building to access additional information (see Figure 1). The presented prototype makes use of position and orientation of captured text for a navigation application and can also display additional textual meta data like language translations or word explanations (see Figure 4). The main advantage of our system is that no further installations in buildings are required in order to use the system.

2 Previous Work

A system which already supports navigation inside buildings is presented by Baus et al. (Baus et al. 2002). The paper addresses mainly the graphical representation of the navigation hints, presenting a resource-adaptive way to support different output modalities and different quality of positions. In an earlier paper presented by Butz et al. (Butz et al. 2001) a similar problem is discussed, where also adaptive graphical representations for navigation are developed. The positioning in indoor scenarios itself is not discussed in both publications. In contrast, Müller et al. (Müller et al. 2005) show a prototypical implementation of an indoor navigation system where special 2D markers are captured by cameras of mobile devices to locate the users. Furthermore, AR techniques are utilized to render a virtual navigation path as an overlay to paper maps, placed at multiple locations inside the building. Other techniques to locate users with mobile devices inside buildings are presented e.g. by Priyantha et al. (Priyantha et al. 2000) or Oppermann and Specht (Oppermann & Specht 2000), however both methods are based on additional (active) hardware components, which have to be installed in order to operate the system. Another field of research concentrates on the utilization of existing infrastructure – i.e. WIFI access points – for localization, e.g. Small et al. show that previously acquired spatial signal strength measurements of WIFI access points can later be used to match location queries that provide the currently received signal strength (Small et al. 2000). Such systems are already commercially available, but even those systems only manage to provide an accuracy of about 3-5m in best-case scenarios. Besides the technique used by Müller et al. all other mentioned methods cannot provide reliable directional information, therefore, additional hardware like an electronic compass has to be used to query the user's direction (Oppenmann & Specht 2000). A location technique that is similar to the system presented in this paper is used by the Semapedia project, where 2D barcodes, so-called Semapedia-Tags, are attached to recognizable objects. However, an application of this technique to the proposed scenario would imply to place a great number of tags inside the building (Semapedia 2007).

In contrast, our work utilizes optical character recognition (OCR) to perform the localization of the mobile client. Previous work for mobile OCR is presented by Kameyama et al. for

Kanji symbols that are recognized on mobile devices (Kameyama et. al. 2005). In the work of Jagannathan and Jawahar (Jagannathan & Jawahar 2005, I) a prototype for mobile recognition of Indian languages is presented. Both papers propose translation as an application to the optical character recognition algorithm. In mobile scenarios perspective distortions of captured images makes OCR an even harder task. Jagannathan and Jawahar present a method targeted for implementation on mobile devices to rectify captured images based on multiple clues, e.g. text lines, document boundaries, etc. (Jagannathan & Jawahar 2005, II). In other work presented by Ferreira et al. the perspective distortion is also corrected based on the text layout. They used multiple steps to perform the correction, where a first fuzzy estimation of the correction provides fast results that are further refined until a required accuracy is reached (Ferreira et al. 2005). Their system is also targeted to mobile devices.

3 Location System Overview

The localization system we propose is separated into two components: A server connected to a database to perform optical character recognition and text matching and a hardware specific client application to perform navigation tasks and access additional information to real-world texts. An overview of the system is depicted in Figure 1.

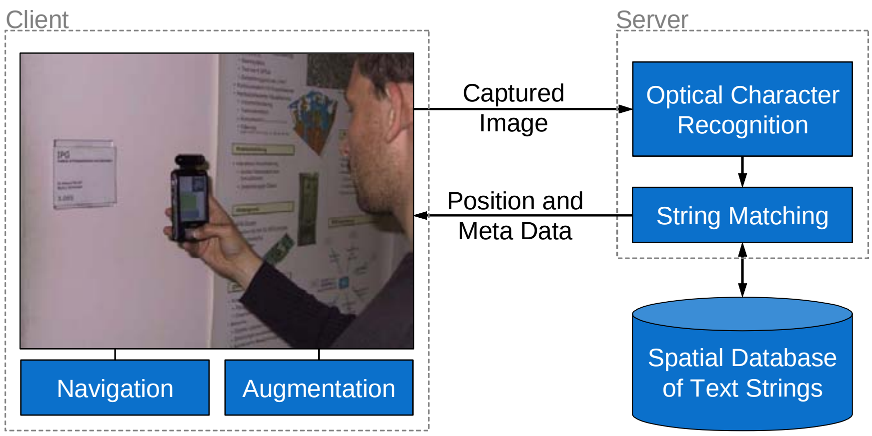

Figure 1: System Overview

3.1 Requirements for OCR-based Positioning

The client device used for the proposed system has to take images of at least VGA resolution (640x480 pixels) that are transmitted to the server. Images with better resolution tend to result in better OCR results, but are larger and, therefore, consume more bandwidth during the transmission to the server. As we focus on mobile devices like PDAs or mobile phones, the server connection varies from MBits (IEEE 802.11 WLAN or Bluetooth) to few KBits (UMTS or GPRS), we found that VGA images provide a good tradeoff. The network connection is required for transmission of the captured image to the server and to receive the result of the optical character recognition from the server, resulting in the user's current location and optionally further information about the text (see Section 4).

In order to be able to deploy the proposed system in an environment, unique text phrases have to be identified. Good examples for such text strings inside buildings are: Door plates or room numbers, unique placards or posters, labeled access ports or switches, etc. It is also possible to support non-unique text phrases, however, the server then provides several possible locations and the client application is responsible to handle this uncertainty (see Section 4). The text passages, in the following referred to as text entities, then have to be acquired and stored on a per-line basis in a database and linked to a text entity with possibly additional information like e.g. the position of the text inside the building. During the evaluation of the proposed system, using our prototypical implementation, we noticed that the low-cost cameras of mobile devices often suffer from extensive lens distortion. This hinders reliable character recognition. Therefore, we propose to optionally let the users calibrate their client camera once, using techniques as available in ARToolKit (ARToolKit 2007). A predefined pattern has to be captured from multiple view points, based on these the software can generate parameters, describing the camera's lens distortion. This information (<100 Byte) can be submitted within the location query, so that the server can perform the correction of the image, based on the parameters. This way, client devices with low computational power do not have to perform the costly calculation.

3.2 Text Recognition and Text Matching

First, lens distortion correction is applied to an image received by the server, if the client provides the necessary information. Afterwards, techniques to estimate the perspective distortion of the text inside the image should be applied. Limiting our system to text strings, techniques for perspective correction based on the text layout could be applied, as presented by (Ferreira et al. 2005) or by (Jagannathan & Jawahar 2005, II). Note that our prototypical implementation does not support this feature; therefore users are forced to capture texts in an orthographic view, which we found awkward in some cases and inadequate for practical use.

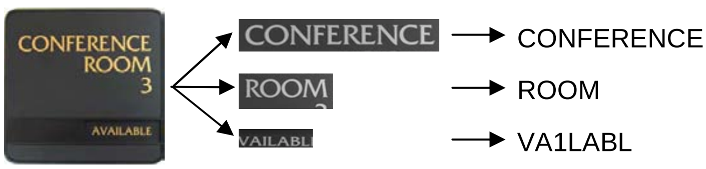

Figure 2: Steps of the optical character recognition: Color reduction, segmentation (left, middle), and optical character recognition (right)

The perspective corrected images are then used for the actual optical character recognition. First, the images are analyzed for the text layout, i.e. where are lines of text, single column vs. two columns format, etc. Afterwards, the segmented image parts are separately sent to the OCR system, as shown in Figure 2. The resulting text lines are then compared to all text strings stored in the database using a fuzzy comparison algorithm with respect to OCR failures. For the string matching a greedy recursive maximum substring matching algorithm was used as proposed by Garris et al. in (Garris et al. 1999). In addition, we adapted the word-error scoring to handle character-matching errors that possibly originate from OCR failures differently, i.e. weight them less intensive. The modified rating function uses a mapping table of recognized characters to a set of possible original source characters (see Table 1) and checks if matching errors disappear if the recognized character is replaced by one of the possible source characters.

Table 1: Character mapping of recognized character to possible source characters

Recognized Character	Possible Original Source Characters
1	I, i, l, /
O	O, 0, c
…	…

This way the recognition result depicted in Figure 2 for the word *AVAILABLE* fails to match the *1* character, but as *I* is within the set of possible source characters it is not ranked as a full character-match failure. As a result of the string comparison, the shortest distance (i.e. smallest error) to a string of the database and its id are stored. The results of recognized lines which belong to the same text entity are combined to find the entity with the smallest overall error. The information associated with this entity – e.g. the entity's position within the building – and the quality of the recognition are transmitted to the client, if the overall error is smaller than an error threshold configured for the server. Otherwise, a error message that no text could be recognized is sent to the client.

4 Location Based Services using Augmentation

With the information returned to the client two primary services are provided to the end users: Indoor navigation and text augmentation with additional information.

4.3 Indoor Navigation

Classical navigation software for outdoor environments is also available for indoor scenarios. Users can select different destinations inside a building and calculate a shortest route, starting at their current location. However, most known systems require additional hardware installations (Oppermann & Specht 2000) or can only provide locations of about 3-5m accuracy (Small et al. 2000). Furthermore, directional information is often calculated via position differences between two location measurements and is therefore only a rough estimation. Thus, users of navigation applications are still required to find the directions, based on the given location, which is for some scenarios – e.g. symmetric buildings or similar looking corridors – a non-trivial task.

In contrast, the proposed location technique can provide highly accurate position and direction information without requiring any additional hardware installations. For that purpose we equipped the server text-string database with additional information about the orientation of each text entity inside the building. In addition, the server calculates the position of the camera relative to the text entity during the perspective correction of a received image. Note that our prototypical implementation does not perform a perspective correction we therefore assume that the camera is facing the text orthogonally, at a distance of about 30cm. The server combines both peaces of information and transmits the global position and orientation to the client.

The user's current view direction can be shown in map drawings, to help them finding their orientation relative to the map (Figure 3, yellow-blue pointer, bottom part). Utilizing orientation for the visualization of navigation information also offers the possibility to introduce augmented-reality techniques, thereby eliminating the requirement of users having to figure out directions themselves. Augmenting the image captured with the client requires a consistent visualization of the navigation symbols, relative to the orientation of the text entity seen in the image. We therefore project the navigation direction, calculated by shortest path finding, to the plane of the text entity. This new navigation direction is used to select and render navigation hints directly onto the real-world captured image (Figure 3, upper right).

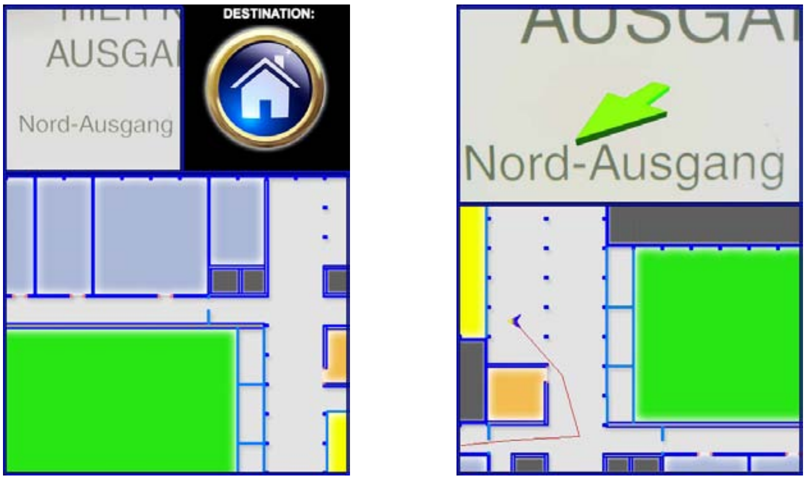

Figure 3: Navigation client interface. Left: real-time camera view with destination and floor map. Right: augmented view after the image capturing showing the direction relative to the sign, map displays location with direction

By such a technique, users only have to face a peace of text, capture it to get navigation hints aligned to their current location and viewing direction. However, a requirement is that the captured text phrases are unique for the area served by the system. To reduce this requirement, feedback to the user – e.g. display hints of possibly unique texts in this building or directional hints where partially equal texts differ – and advanced visualization techniques can be applied. Users may be informed of multiple possible locations of the captured text showing the uncertainly of each, based on the string matching error, former positions and the time period between, or statistics on likely user locations. Already depicting the density distribution where the captured texts occur most often may help users to find their way.

4.4 Information Augmentation of Real-World Texts

In a similar way as the systems proposed by (Kameyama et al. 2005) and (Jagannathan & Jawahar 2005, I) for translation of texts to other languages, the server component in our system can attach additional meta data to the recognized text. Even further, dynamic information can be generated, based on multiple context aspects – e.g. client device type, user settings, time, date, etc. – and transmitted to the client. Using small information icons, also displayed using AR methods, result in an intuitive user interface where users simply have to click on the icons embedded in the captured image to access the additional data. The required information and the image-space positions for the overlay icons are generated by the server. Therefore, the text-string database allows defining meta data to text entities, but also for arbitrary substrings of each stored text line. Our current implementation of the prototype makes use of this feature to support hyperlinks to websites within real-world texts (*H* icon) that are only displayed if the device has an internet connection. In addition, the server generates translations to a user-defined target language on a simple per-word basis (*T* icon) and performs a search query on the free web-based Wikipedia Encyclopedia (*W* icon). The left image of Figure 4 illustrates the information augmentation for real-world texts, after clicking on the *W* icon right above the world *Photogrammetry* the application view changes to show the description queried from Wikipedia (Figure 4, right, only the first paragraph is shown). Please note that we deactivated the translation functionality, otherwise each word would have an additional *T* icon associated. Other icons are handled similarly, e.g. by clicking the *H* icon the associated web site is shown in the lower part of the screen.

The demonstrated interplay of camera images and direct interaction on augmented texts using a pen device characterizes an intuitive user interface to access relevant information of the user's current environment. The interaction is thereby limited to single pen tips or button pushes, multi-modal buttons or textual entries using techniques like virtual keyboards or handwriting recognition are replaced by a simple image capturing of the relevant text phrases.

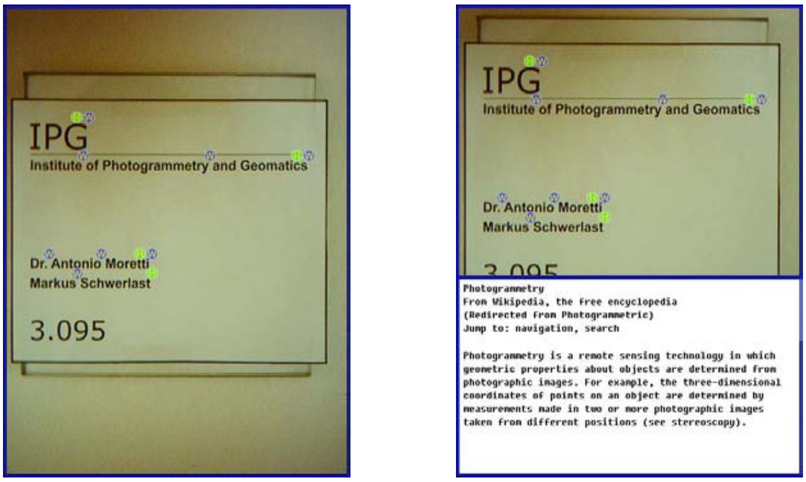

Figure 4: Augmented view of a captured text image. The icons (H and W) mark clickable interaction widgets to display further information (shown in the right image for Photogrammetry). H refers to a web-based homepage and W shows the first paragraph of a search query to the Wikipedia Encyclopedia using the associated word

5 Implementation and Results

For evaluation purposes we implemented prototypes of both system components. The server was realized as a C++ daemon, running on a Linux machine. The network communication is managed via a per-client thread using a low-level socket communication to minimized network-bandwidth requirements. We integrated the open-source projects OCRopus (for document layout analysis) and Tesseract-OCR (for character recognition) to implement the character recognition (OCRopus 2007, Tesseract-OCR 2007). The OCR-fault-tolerant string matching is based on the method by Garris et al. (Garris et al. 1999) with a modified word-error rating algorithm described in Section 3.2. The text-string database is stored in a XML representation and entirely loaded into memory during runtime, however the required memory the service is still less than 4MB for 500 text entities.

For testing, we deployed the daemon on a server machine running a 2.8GHz CPU and setup a database of 500, 2000, and 5000 text entities, each 4 lines of text with about 4 words on average. For performance evaluation we measured the time for the OCR on the received images and the subsequent string matching separately. We found that the performance of the character recognition depends on the captured image quality: If the images contain high-frequency noise, the recognition process slows down. However, for 640x480 resolution images with moderate quality, as seen in Figure 4, the server takes less than 0.4s for the OCR processing. The string matching depends on the number recognized words and on the number of text entities contained in the database, the results are presented in Table 2.

Table 2: Performance of the string matching for different setups. Four text lines were matched with the database, where on average each stored text entity contained 4 lines of text with about 4 words

Number of Text Entities in the Database	Time in seconds to evaluate best matching text entity
500	0.13s
2000	0.59s
5000	1.44s

Therefore, the overall performance of our current implementation is dominated by the network transfer rate of the WLAN connection, as the transmission of the raw 640x480 images (~ 1MB) from the client to the server takes about 2s. The results of the server typically contain much less data and can therefore be transmitted to the client much faster.

For the client prototype we used a Windows Mobile 2003 PDA with an Intel XScale PXA263 400MHz CPU, also programmed using C++. The application uses direct-screen access for drawing into the 480x640 resolution framebuffer and, thereby, achieves good interactive framerates of about 6-12 frames per second (e.g. when scrolling the floor-plan map). The memory requirement dependents on the 2D floor plans downloaded to the client, where the raw data of each 2d map of about 1000x1000 pixels resolution occupies about 3MB. A problem of the current client implementation is the acquisition of the camera image. We equipped our prototype with a simple CF-Card camera which took approximately one second to capture a 640x480 image, requiring the users to hold the camera very still to achieve an acceptable image quality, without too much motion blur.

We showed the prototype during a public event at university where visitors were allowed to tryout the system and navigate themselves inside the building. Most of the participants found the system very useful and were able to operate it instantly, they also liked the idea that no additional hardware is required and client application could even run on most modern camera-equipped mobile phones.

6 Conclusion and Future Work

We have shown an intuitive mobile system that supports users in accessing information and navigation inside buildings. The system does not require any additional hardware installations like location systems or markers. Existing wireless infrastructure – WLAN or GPRS – is used to transmit captured images containing text to a server, which tries to find a mapping of text phrases to additional meta data like position, orientation, or language translation utilizing OCR. The returned result is presented on the client device as an overlay to the real-world images using augmented reality techniques. This allows an intuitive presentation, especially of navigation symbols, which users easily understand and benefit from. The prototypical implementation of the recognition system also shows that the performance is still adequate for the presented application even for big configurations of 5000 text entities.

In future we will further optimize the proposed system including the perspective correction of the captured images and an image compression on the client device for transmission to the server. We also want to investigate a hybrid system where parts of the OCR method – i.e. the document layout analysis – are performed on the client device to be able to transfer only important parts of the image to the server.

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UCD in Wearable Computing – A Case Study

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Abstract

This paper reports experiences with applying UCD methods obtained during the development of a wearable prototype for the ward round in a hospital. Considering the non-computer related primary task in the design of the wearable system introduces a number of issues to applying existing UCD methods. This paper identifies a number of challenges that arise using specific UCD methods, as well as challenges that cut across the whole UCD process. These challenges and their implications are briefly discussed. However, the main focus lies on uncovering the breadth of problems.

1 Introduction

Wearable computing has been an active research topic for quite a while. While many of the technological challenges have been solved, there is an increasing demand for research in the area of usability. Wearable computing considers scenarios where today's desktop and mobile solutions are inappropriate. Unlike well researched desktop or mobile scenarios, users in wearable computing are away from their desk and have to carry out complex tasks in the real world. According to Gorlenko and Merrick (Gorlenko & Merrick, 2003) we call this kind of scenario the field context. The primary task requires most of the user's attention that often cannot be redirected to the computer. For this reason end user involvement becomes very important. Therefore, applying UCD principles to the development process is a natural choice. However, current research in mobile usability (Kjeldskov & Stage, 2004) shows the insufficiency of the available usability engineer's tool set. With wearable computing scenarios the problems are magnified, because the user's primary task needs to be integrated into the interaction.

The question of how to successfully apply existing UCD methods in such settings is still an open issue. Practical research on this topic is rare. This paper focuses on the challenges and pitfalls when applying UCD to wearable applications. The reported experiences were gained during the development of a wearable prototype for the ward round in a hospital. In a first step, potential use cases for wearable technology were identified in cooperation with the hospital staff. User observations, interviews and focus group discussions revealed a scenario focusing on the ward round. Several UCD activities were carried out resulting in a usability test of the final prototype.

The remainder of this paper is structured as follows: section 2 investigates related work regarding the application of UCD in non-desktop scenarios. Section 4 describes some of the UCD activities applied and discusses problems encountered because of the field context setting. Section 5 focuses on issues independent of the methodology used. Section 6 finally draws conclusions and indicates necessary future work.

2 Related Work

Wearable computing research is still quite young and most research still concentrates on getting the technology and infrastructure right. There is not much research addressing the question how to adapt the software development processes to the particularities of the field context.

Terrenghi et al. investigate how the mobile context of use changes the requirements engineering process and which new issues need to be taken into account when user centered design is applied to a mobile scenario (Terrenghi et al. 2005). However, their focus is purely on mobile applications. No insights how UCD methods need to adapt to these new issues are provided. Gorlenko and Merrick (Gorlenko & Merrick 2003) describe the differences between desktop applications, mobile office context and field context. They argue that everyone involved in developing applications for the mobile office and field contexts must focus on the total user experience. They also describe why current UCD methods are not well prepared for developing for the field context. The paper discusses effects of the field context on observations, task analysis, prototypes, design evaluation and validation. These papers discuss UCD issues in theory. The works are not based on hands on experiences collected during design of such applications. In fact, most papers published in this field are of a rather theoretical nature.

However, there are some notable exceptions. Kangas et al. (Kangas & Kinnunen 2005) report experiences with UCD activities which were collected during development of two mobile phone applications. Although these applications belong to the mobile office context, the recommendations given are also valid for the field context. Relevant questions in both contexts are the need for real prototypes when testing new interaction styles and the question whether lab testing is feasible when the context of use might have a high impact on usability.

Kristoffersen et al. (Kristoffersen & Ljungberg 1999) investigate computer support for inspection and engineering in the field. One of their important findings is that the challenges of mobile computing aren’t solely a result of the limitations of devices, but also of the work situation at hand. This is because the user needs to “make place” for the mobile device if it is not specially designed for the situation. Their goal is to design mobile applications in a way that allows interaction to “take place” without interrupting the user’s primary task. This is also one of the most important aspects when designing for the field context.

3 Case Study – Ward round

During the ward round, doctors need bedside access to patient records. In a paperless hospital of the future, patient records may be displayed and searchable via a bedside display. Beyond accessing patients’ records, doctors need to record findings and setup appointments for further patient treatment. Both, the findings and the appointments have to be stored in and synchronized with the hospital’s information system immediately. The scenario as such does have several challenges one has to cope with:

- The several tasks the ward round is actually comprised of are done in collaboration between doctor(s) and nurse(s).
- Whenever getting into physical contact with the patient, doctors must disinfect their hands before they are allowed to operate any non-medical equipment again. To disinfect, the doctors need to interrupt their current task, walk to a dispenser mounted on the wall. After disinfecting, the hands remain wet for some time preventing immediate use of any equipment. Therefore, contact free interaction methods seem to be promising in order to save time.
- Task switching as such is a major challenge not just because of the fact that when using a computer our users have to switch between their primary task and the computer related task but also because task switching is necessary while doing the primary task itself (e.g. examining the patient, discussing with the patient and the nurse).

The prototype was developed as part of the wearIT@work project. wearIT@work is a European Union funded project running under the auspices of Framework Program 6, involving 36 partners from across Europe. The design and development followed an ISO 13407 compliant UCD process model. The different methodologies discussed in this section covered the first of four planned iterations of the process. The UCD process started with initial field observations, interviews and focus group discussions on site. The outcomes of these investigations were basic workflow descriptions, general usability requirements and initial design ideas. These ideas were evaluated in a subsequent study based on UI mock-ups. In line with the study’s results, requirements for a prototype were defined. Later, the requirements were discussed, evaluated and prioritized together with end users. Then a prototype was specified taking the most important requirements into account and using technology, available to the project (provided by partners working in various fields of hardware and software development). Finally, the prototype was set up on site and tested by a group of doctor/nurse pairs.

The effects of the field context on the various process steps varied. Therefore, the next sections describe only those process steps in more detail where interesting challenges specific to the field context were experienced.

3.1 Field Observations

Early in the project a series of observations was conducted, where doctors were shadowed during their daily ward round. The goal was to discover the activities performed during a ward round, together with information about the environment and its influences on the doctor's work. To integrate the system seamlessly with the current ward round process, quantitative data about exemplary instances of the current process was necessary to analyze typical work situations. Because activities during a ward round change frequently, a fine grained capturing of executed tasks within a range of seconds was necessary. This quantitative data also showed how often situations occur and how long they last.

During the observations, a number of challenges were encountered. First of all, the environment was completely unknown to the observer. When observing office users the basic setting is already known in advance and the observer has first hand experiences with this kind of settings. A ward round, however, is most likely new to an observer. As a consequence, it was difficult to assess the importance of events and environmental factors as well as to note the right things.

The speed at which unknown activities take place is another challenge the observer has to cope with. The ward round is a highly optimized and parallelized process. For example, a doctor might read the patient's file, order an examination, talk to the patient and document his visit, all in less than a minute. In a typical approach, one would interrupt the doctor and ask for clarification when things went too fast and were not understood. However this approach is prohibited by the very environment that is studied. The doctor is not performing the ward round in his office, but in the hospital based on a strict schedule. In the present example, the hospital administration did not approve any technique that would have interrupted the ward round or would have made the patient aware of the fact that a study was in progress. For this reason and also for privacy reasons, audio and video recordings were not allowed.

Jotting field notes on paper worked for the initial observations when trying to uncover the breadth of activities and environmental influences. However, capturing detailed temporal data during the observation was only possible with computer support (Klug 2007).

3.2 Mock-up evaluation

Based on observations and interviews, first design ideas were generated. Those ideas were evaluated using a mock-up system. The system allowed the doctor to view patient records on a Tablet PC and gave the nurse the opportunity to complete x-ray request on a PDA. The studies, which were done using the mock-up, pursued three goals:

1. Evaluate the feasibility of using the selected devices during the ward round.
2. Analyze whether the distribution of tasks between doctor and nurse was practical.
3. Compare speech and pen input as suitable input modalities for the Tablet PC.

All evaluation results were purely qualitative, no quantitative data was collected. The mock-up system simulated two tasks: browsing the patient's record and ordering a new examination. The idea was to guide the doctors and nurses through a few scenarios. To perform the studies in a realistic environment, a normal patient room with bed, chairs and tables was used. The UIs on Tablet PC and PDA were implemented using Macromedia Flash. Whereas pen input was already part of the Tablet PC; speech input was simulated using the Wizard of Oz approach.

For the sake of simplicity only some navigational paths through the dialogues of the user interface were implemented. Therefore, it was important that only available functions were chosen by the participants. Invented patient cases were supposed to lead the doctors through the UI of the mock-ups. In case of a problem, the participants were given hints by the examiners.

According to Hagen (Hagen et al. 2005), enactments entail role-play and enacted scenes, allowing the user to interact freely with the system in the right context. Usually, and in contrast to simulations, no tasks are predefined. Therefore, the approach chosen represents a mixture between enactment and simulation.

The doctors and nurses mostly followed the implemented paths of the system. Anyway, sometimes the implemented paths spoke against a doctor's 'intuition', such that s/he was reluctant to continue. This led to long discussions and the tasks were not completed. In these cases, the workflow was interrupted and an analysis of the workflow‘s suitability became impossible.

Beyond the aforementioned problem, some influential factors of the ward round could not be considered. For example, the patient as the center of attention and a trigger for most actions could not be included in the study. Furthermore, the participants did not perform their tasks under time pressure common during the ward round.

Despite these limitations the setup included enough context to evoke feedback about practical aspects of the workflow and devices. The Tablet-PC was regarded too heavy by most participants. Additionally, the device interfered with the physical patient-doctor interaction because there was no place to put it down in a patient room where it would not have been contaminated. Lastly, the Bluetooth headset for speech input could not be used together with a doctor's stethoscope. These aspects would practically not have been discovered without doing tests within the considered context.

This findings show the importance of considering the context of use in the test setup. Even an incomplete setting can lead to important findings. Especially during initial evaluations where the focus is less on performance evaluations, every piece of context that can be easily reconstructed can be of value.

3.3 Usability Test

Based on the results of the mock-up evaluation and requirements gained through further focus group discussions, a first prototype was designed and built. There were several reasons why the Tablet PC wasn't the best solution for enabling access to patient data. First, the Tablet PC is not comfortable enough, because using it disrupts the usual workflow. Second, disinfection is required between getting in contact with the patient and the device. The Tablet PC was therefore replaced by a display attached to the patient's bed and gesture interaction. An interaction wristband was used to recognize arm gestures. Those gestures were used to navigate the application.

The goal of the usability test was to evaluate how well task switches, i.e. examining the patient and interacting with the system work and how the chosen gesture interaction fits with the ward round setting. Another goal was again to evaluate the suitability of the collaborative workflow between nurse and doctor. As the gesture recognition technology was fairly new for our user group, an initial study with university students was conducted. The initial study identified technical and practical issues with the gesture recognition system and helped us to increase the reliability and usability of it.

In terms of physical context, the prototype experiment was set up like the mock-up experiment. However, a dummy - normally used for educational purposes - was added to play the role of the patient as shown in Figure 1. The dummy enabled a more realistic performance of physical examination tasks, which was necessary to achieve the goals of the study.

Figure 1: Test setup for the usability test showing the bedside display and the dummy.

Although the doctor's new user interface was fully functional, a simulation rather than enactments was used because of the experiences in the mock-up evaluation. The doctor was supposed to view several documents and examine the patient once in between. This was achieved by instructions contained in the documents which simulated the patient records. Consequently, there was little room left for participants to deviate from the planned sequence of actions. All relevant interaction steps were performed by the participants, even though the content of the documents and scenarios was not realistic. However some doctors performed the physical examinations a bit nonchalantly and not at all to the same extent as they would have done it, had there been real patients. Consequently, the influence of the examination task on the gesture interaction was unrealistically small. Therefore, the overall interaction paradigm could be evaluated; switching between physical examination and computer task could not.

Using a simulation instead of an enactment turned out to be the right choice. Because the task sequence of browsing arbitrary documents was not too realistic in a medical context, the doctors had no problems doing the “wrong” thing.

4 General issues using UCD

The issues described in the previous section were a direct result of the particular method which was applied in this specific context. We encountered also some general issues directly resulting from using UCD in the field context. These general issues had an impact on all activities carried out and are likely to have impact on other methodologies as well.

4.1 Lab vs. field testing

When evaluating computer systems developed for the field context, there are two basic approaches: testing in the lab and testing in the field. Testing in the field means evaluating the system in its target environment, e.g. testing GPS navigation software while driving a real car. Lab testing on the other hand means reproducing parts of the context of use in a controlled environment. The selection of the appropriate method depends on the goals of the study and on the context of use itself.

Field tests ensure a realistic primary task as well as physical and social contexts. A successful field test allows the most precise predictions about the usability of the final product. However, field testing has also drawbacks. Even though providing the most realistic context, field evaluations are resource intensive. There are also many variables involved affecting the interaction with the system, which can be difficult to control. Therefore, if usability problems are detected, it might be difficult to discover their cause. Another issue is the amount of functionality that needs to be implemented before a field test can be done. In the ward round scenario, a field test is impossible without access to the hospital’s patient data.

Lab testing, on the other hand, can be done with mock-ups only. When evaluating in a laboratory context, it is also possible to control all the variables. Here the examiner needs to choose the aspects of the context of use, he wants to include in the study. Because the context of use is only approximate, the quality of usability and performance predictions depends largely on that approximation. If important aspects are missing, the results might be completely invalid. Another challenge is to ensure that context simulations in the laboratory are as realistic as possible, especially when aiming to simulate a primary task, like the examination of a patient.

A reasonable amount of research has been performed where the physical context of use was simulated in the laboratory (Kjeldskov & Stage 2004; Baillie & Schatz 2005; Been-Lirn Duh et al. 2006). However, there are not many results available regarding the simulation of the primary task (Witt & Drugge 2006).

In our case study for both, the mockup evaluation and the usability tests, a laboratory context was chosen for several reasons. Firstly, the prototype was not fully functional in the sense of being integrated with the hospital systems. Thus, no real patient data could have been accessed and no real examination orders could have been entered, which would be unpractical when dealing with real patients in the field. Secondly, most of the doctors had no prior experience with a similar application and especially not with gesture interaction. Thus, it was expected that a great deal of attention and time – which cannot be spared in a real ward round - would be required for interacting with the system. Thirdly, the involvement of real patients in the experiment was not possible due to privacy reasons. Fourthly, it would not have been possible to control which and how often primary tasks were performed. Thus, it would have been difficult to make sure that the important interdependencies between human computer interaction and the primary task were actually present and that these could be individually accounted for. Of course, some of the factors present in the reality like time-pressure or natural communication with patients or colleagues could not easily be simulated.

4.2 Involving the Non-User

Moving away from desktop scenarios, computers will be spread everywhere. Herstad (Herstad et al. 2000) introduces the non-user as “a person, or group, that is not directly using the technology in question, but that at the same time is affected in some way by the use of technology”. The authors motivate non-user involvement in the design process. In the healthcare scenario, doctors and nurses are the end users of the introduced system, and wearable computers will influence the doctor’s surroundings. Patients are a major part of these surroundings. Motivated by a strong demand for a better patient treatment in the healthcare sector, the patient’s well-being is very important. Privacy issues restrain contact to patients and make patient’s inclusion in the design phase impossible. Instead, the patient’s view is mainly based upon doctors’ and nurses’ comments or the designer’s appraisal what makes it impossible to be evaluated.

The doctors’ and nurses’ comments regarding the patients’ view resulted in two assumptions affecting the proposed interaction methods for the ward round prototype system. First, patients will be annoyed by speech interaction. They will feel addressed if doctors use speech commands to navigate through the system. Second, they will be bothered by obtrusive navigation gestures. In other healthcare scenarios, e.g. when patients will be anaesthetized, speech interaction might be an adequate interaction solution. Nurses clearly know the processes of a ward round, therefore they will not be distracted by the system as non-users. Interviews and focus group discussions revealed another interesting effect. Doctors were worried about how using gestures might affect their relationship with the patient. They were concerned to make themselves look strange performing gestures. Involving the non-user is therefore quite important to eliminate any wrong conclusions about any impact of users on non-users and vice versa.

4.3 Communicating HCI findings

Another challenge of designing for the field context is communicating the scenario and related requirements to designers, developers and colleagues. Usually these team members have not experienced the scenario at a first hand, but still need to get a feeling for the scenario. When developing for an office context this is less of a problem. The office context is well known. Team members can mostly rely on their own experiences when designing or developing. The field context differs strongly from the office context in terms of the primary tasks and the environment. Discovering these differences is exactly the goal of many user centered activities. However, only a small number of team members can be directly involved with the end users. The rest of the team needs to be informed about the scenario through presentations and written reports.

The described case study proved that it is difficult to capture all aspects of the ward round in a written report. No matter how detailed the descriptions were there was still room for misunderstandings. When these misunderstandings are not discovered or the HCI expert is not available for discussions, this can lead to serious design problems.

Existing UCD methodologies like contextual design (Beyer & Holtzblatt 1997) try to capture information about the work environment and the sequencing of activities in graphical models to ease the understanding of the context. However, they offer only simple graphical notations. The ward round for example does not consist of strict sequences, but parallel activities that cannot be represented in sequence charts. Also information about modalities used for these activities is not captured.

The use of timing diagrams of concrete scenario instances for communicating temporal aspects of a primary task, as proposed by Klug (Klug 2007), is currently being investigated. Diagrams like these can be captured during observations as described earlier.

4.4 Conclusions and Future Work

This paper identifies challenges and pitfalls one has to cope with when applying UCD to scenarios in the field context based on a case study.

The field context adds new challenges to stationary and mobile scenarios. It requires the application of UCD as a must while leading to problems with established UCD tools and methods. Field observations, usually delivering mostly qualitative data about the scenario have to be extended in order to collect quantitative data and information, to allow an analysis of how a computer task can be performed in parallel. The decision whether to apply lab or field tests becomes more difficult when designing for the field context, because of the increased importance of the user’s context and primary task. Whether to perform tests using simulation or enactment turned out to be another question. For the case study described here, simulation was given priority in order to achieve a higher level of control enabling the testing of particular functionalities of the mock-ups/prototypes. Further research is clearly necessary to adapt UCD methods and tools to the field context.

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Innovative Experiments enable Wearable Applications' success

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Abstract

Interaction and usability aspects of software systems are critical software quality measures. This paper highlights the necessity of research and development on specific user-centered and work process oriented topics in the innovative field of wearable computing. The different phases of the development process as well as experiments performed to implement the actual applications will be presented. This is done in order to implement an application to support aircraft maintenance tasks with wearable computers.

1 Introduction

Interaction and usability aspects of software systems have become critical software quality measures. Today, more attention is paid to a proper user interface design and its seamless integration into the general software development process. When considering applications for wearable computers many challenges, different to traditional desktop applications, arise (Starner 2001, Baber 2001). For instance, understanding interaction design or the appropriate use of sensor-based context information are two critical factors that decide whether or not wearable computing will ever hit the market in the nearer future. In particular, this is because the usability of an application (which is closely related to performance measures) is getting more important and may even overweight cost measures of industrial applications (Obrenovic & Starcevic 2006). One of the first comprehensive reports on the design of a wearable computer including its application is described in (Bass et al 1997). Although wearable computing has not yet reached the market, research has proposed a few demo applications for different domains. For example, (Boronowsky el al. 2001) developed an application that supports crane maintenance. For this, a combination of a visual interface that can be operated with a data glove device was proposed. In (Witt et al. 2006) a similar concept was used to support aircraft technicians. Besides this maintenance related application examples, there are also others (Drugge 2006, Haniff & Baber 1999).

To support aircraft maintainers during their daily mobile work, wearable computing is deemed to be a promising technology (see e.g. Nicolai et al. 2006). Wearable computers can be unobtrusively worn on body to support a user during work. Unlike to stationary computing where users mainly concentrate on one task to be performed with the computer, wearable computing typically expects users to accomplish two different tasks (Drugge et al. 2006). A primary task involves real world physical actions, while the secondary task is often dedicated to interaction with a wearable computer. These unique characteristics, however, call for new interaction concepts and user interfaces. Findings from stationary HCI can often not be applied directly to interface design for wearable computers (Starner 2001). Thus, new user studies examining particular properties of HCI for wearable computers are needed. The wearIT@work project (WearIT@work 2004) was arranged to investigate these issues with a user-centered approach. It is supposed to empower mobile workers with real wearable computing applications. Here, questions particularly arose with regards to the impact the real end users involved in the application development process will have on experiments conducted to investigate how wearable interfaces and applications have to be designed to meet end user requirements. Meeting these requirements will have strong impacts whether wearable computing will enter industrial branches or not.

Compared to commercial leisure-applications or –services in the field of mobile devices like cellular phones wearable industrial applications have to be much more specific in order to fit the requirements and to become a “Killer-Application”. Acceptance in industrial environments is much more triggered by the usefulness, functionality and robustness and less by fanciness.

In paragraph 2 the background is presented, paragraph 3 presents an approach for developing wearable applications in order to incorporate the demands of industrial environments. In paragraph 3 selected Experiments are also presented to illustrate how to explore innovative concepts in presented environments. Paragraph 4 is the conclusion.

2 Background

Project outcomes of the above mentioned wearIT@work project will be tested and proven by realistic pilot applications in a number of practical and relevant application domains where wearable computing has the potential to enhance existing processes. Thus, our research concentrates on the development of applications that follow a user-centered approach with focus on the mobile worker and his/her needs. For this, project partners cover various multi-disciplinary backgrounds involving experts from computer science, engineering science, cognitive science, ergonomics, design, psychology, and sociology. The research background presented impacts the domain of aircraft maintenance which is one of four industrial scenarios of the project.

The main driver for our experiments were the missing information about how aircraft maintainers feel and behave when using specific wearable user interfaces that are usually controlled by novel interaction devices beyond those known from desktop systems. To examine these questions we started with interviews and workplace studies at an aircraft maintenance service facility to identify maintenance procedures suitable for a realistic experiment to evaluate different wearable input devices. Due to the involvement of domain experts in the experiment a set of real maintenance procedures was needed to motivate maintainers for participation. The main requirement of domain experts expressed during interviews regarding a wearable computer use was that is has to support and ease maintenance tasks and should be easy to operate.

The focus of this paper is to state that the simple provision of technology e.g. software-frameworks for Wearables, or any other hi-tech equipment may be enough for commercial leisure markets and their applications for mobile devices (e.g. cellular phones and their services). This does not hold for industrial branches and wearable systems. End-Users differ from leisure markets, professionals, particularly mobile workers like aircraft maintainers, do judge systems from the efficiency and the added value of the system. As a consequence very specific research has to be performed; experiments with real End-Users have to be conducted.

3 How to develop a wearable application

An approach will be presented which was proposed by (Morales Kluge, Witt 2007) which makes use of a toolkit to develop a wearable application (Witt et al. 2006). This approach considers the importance of the End-User in the research and development phase of a wearable application by involving him strongly in the requirements and evaluation phase. The author's insights coming out of the interviews with real End-Users working in industrial environments suggest that acceptance of a wearable system (application) is mainly driven by the ability of the wearable system to solve End-User's problems in their daily work. This requires knowledge about the targeted field and very specific experiments that address End-Users' problems.

Two specific examples of experiments will be presented that are located thematically in the field of aircraft maintenance that are a snapshots taken out of the development approach (cycle) shown in figure 1 and are basically located at step 3 of the approach.

3.1 The Approach

Through several workplace studies at the operators working environment the requirements for the envisioned application have to be elicited. One key element for the whole development process is the end user and its needs. Another key element is the benefit that should emerge out of the introduction of wearable systems in industrial working environments. By conducting interviews with several aircraft maintainers and by observing those while working requirements were identified for the application and its functionalities as well as crucial prerequisites for the introduction of innovative wearable systems. The development process followed this approach:

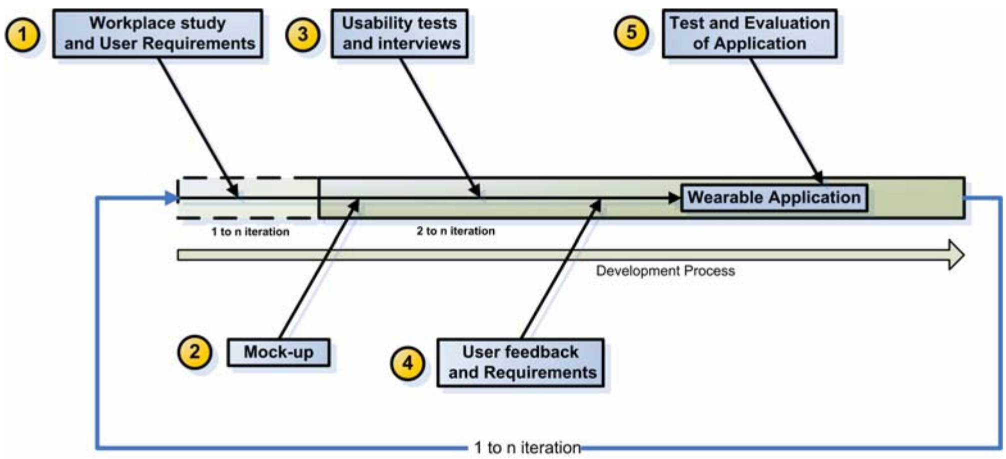

figure 1: Application Development Process

1. Workplace study and User Requirements

   This phase contains the elicitation of the users' needs and the understanding of the working environment and the existing problems in general and the ones addressing the wearable system.

2. Mock-Up

   The Mock-Up is the first specific prototype that addresses the identified problems in form of an experiment set-up that allows creating quantitative and qualitative results.

3. Usability tests and interviews

   Here the mock-up from phase 2 is used to perform the tests (experiments) with the needed number of subjects (real End-Users should be preferred).

4. User feedback and requirements

   Measured metrics (e.g. performance measurements) and interview results (questionnaires) are the outcome of this phase.

5. Test and evaluation of the application

   This is the last phase in one development iteration where the results of phase 5 are integrated into a demo application that has to be tested under real conditions.

3.2 Example 1: Usability Tests of Input-Methods

To examine usability questions for aircraft maintenance, interviews and workplace studies at an aircraft maintenance service facility were carried out to identify maintenance procedure steps suitable for an experiment that tests different input devices for wearable user interaction. The involvement of domain experts required a set of real procedures to motivate maintainers for participation in the experiment. The main requirement of operators was the support of complex maintenance tasks by wearable systems. A maintenance task dealing with the circuit breaker panel 800VU in an Airbus A300 was chosen for an experiment (see figure 2). The tests were performed in a real aircraft with 10 domain experts and at lab conditions with laymen (20 subjects) at the University of Bremen.

figure 2: Test conditions: real (left), lab (right)

The setup involved three different user groups and three different wearable input devices (pointing device, data glove, and speech-interaction). As a base case the traditional mouse (pointing device) input device was chosen; giving subjects confidence with a familiar device and to avoid fear. More innovative input devices are represented by a data glove (gesture interaction) and speech interaction. Users will then be given oral instructions to navigate through a multi-layered menu structure presented on a Head Mounted Display (HMD) (see figure 3). Two different navigation paths with changing navigation length had to be performed for each device.

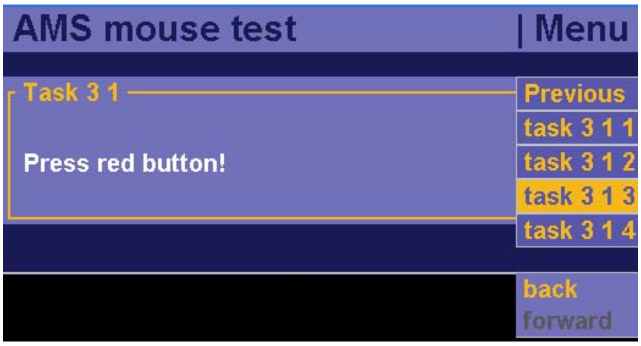

figure 3: Screenshot of the navigation task shown on a HMD.

By observing the user's performance in the navigation task and the accuracy of the navigation, i.e. the deviation from the optimal path, conclusions can be drawn on (1) what type of wearable input device is the most efficient (in terms of task performance) and appropriate for a particular user group and on (2) the differences between the type of subjects: Domain Expert vs. Layman.

3.3 Example 2: Calibration Experiment

Again this experiment starts with the first step of the proposed design approach which are the workplace study and the interview phase. Located in the field of aircraft maintenance this experiment was abstracted from the interviews with the maintenance operators and the according maintenance manual tasks. It became clear that calibration of components/systems of aircrafts is very time consuming and could be done much faster with an appropriate wearable system. The challenge in this scenario is to find a suitable feedback method that does not interrupt the primary task of calibrating an aircraft system. The primary task of the experiment represents general calibration tasks. As an abstraction of those tasks, in a controlled laboratory environment, the adjustment of a four-leg table is used (see figure 4). To adjust the table to a predefined alignment on two axes, height adjustment screws mounted underneath each table leg are used.

A single test session consists of one practice round where the subject gets to understand each feedback method (2 graphical, 1 textual), followed by one experimental round during which data is collected for analysis. Collected data consists basically of measured time subjects needed to perform the whole calibration task or even subtasks (calibration time for one specific leg). The time to complete the primary task naturally varies depending on how quick the subject is.

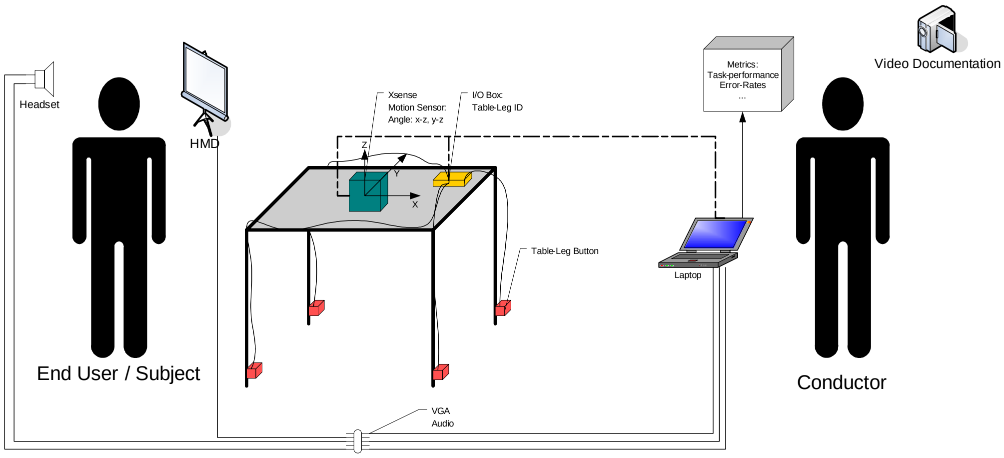

figure 4: Experiment set-up "Calibration Experiment"

In the end of the experiment subjects will be provided with questionnaires to record qualitative data used for later evaluation, e.g. to gain user acceptance measures. Additionally, ethnographic data and data based on a questionnaire from the social science consultant will be collected.

The apparatus used in the experiment consists of a wearable computer (OQO), an HMD, and a special textile vest designed and tailored to unobtrusively carry all equipment as well as all needed cablings for the HMD without effecting the wearers freedom in movement. The hands of the user are free.

The feedback provided to support calibration tasks is either presented on a HMD from or given through an audio headset.

To measure the alignment of the calibration task abstraction object (table) an XSense MT9 motion sensor is used to acquire needed pitch and roll values. It is mounted on top in the centre of the table. For the purpose of subject post-hoc motion analysis and to determine problem-solving strategies dependent on the feedback methods presented, a button is mounted to each leg of the table. Subjects have to press first the button mounted on the leg of the table to indicate their proceeding adjustment of the height adjustment screw of that particular leg. Button pressed events are logged in the central log file of each user.

Analysis of the gathered data (quantitative: task completion time, qualitative: questionnaire results) draw a picture of the ranking of the presented feedback methods in a calibration scenario. This helps developers choosing an appropriate feedback method for tasks where the primary task consists of calibrating systems.

4 Conclusion

This positionpaper wants to point out the necessity of specific experiments for exploring new concepts for HCI means in Wearable Computers particularly in industrial environments where users differ from what is known from (leisure) mobile device users. Real existing problems of work processes should be the basis of further research in order to create acceptance and in order to enter industrial branches.

Besides creating (technical) frameworks (services) and the basic infrastructure for wearable systems it is getting more and more important to focus on very specific demands of the industrial environments that come out of the work process and the End-User. Due to the nature of wearable computing, being seamlessly integrated in the personal environment of the user, wearables should also be integrated seamlessly in the work process which requires research on how to achieve this.

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Ansätze zur formativen Evaluation des Einsatzes dezenter mobiler Endgeräte zur Administration in Schulen

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Zusammenfassung

Dieses Positionspapier stellt eine Idee zum Einsatz mobiler Endgeräte für administrative Zwecke in Schulen sowie Ansätze zu deren formativer Evaluation vor. Zur Erfassung von Daten im Klassenraum sollen verschiedene mobile Endgeräte eingesetzt werden, um die Daten direkt in nachfolgende Systeme einspeisen und aktuell vorhandene Medienbrüche abschaffen zu können. Zugleich sollen mobile Endgeräte eingesetzt werden, die aus Nutzersicht möglichst wenig auffallen, also dezent sind, damit sie für Lehrkräfte keinen zusätzlichen Aufwand generieren. Im Rahmen der Evaluation werden daher verschiedene Endgeräte (PDA, Handy, digitaler Stift) in Vergleichsgruppen eingesetzt, um ihre jeweiligen Vor- und Nachteile im Kontext Schule identifizieren und Hinweise für die weitere Entwicklung liefern zu können.

1 Einleitung

Der Einsatz von IT an Schulen wird bislang ganz überwiegend im Hinblick auf die mediale Unterstützung des Unterrichts thematisiert. Demgegenüber spielt die technische Unterstützung von Verwaltungs- und Entscheidungsprozessen noch immer eine untergeordnete Rolle. Es ist davon auszugehen, dass mit neuen Maßnahmen zur Qualitätssicherung und der damit verbundenen externen Evaluation im deutschen Bildungssystem sowie der Verlagerung von Kompetenzen auf die einzelnen Schulen erweiterte Berichtspflichten verbunden sein werden. So haben die Bundesländer Orientierungsrahmen zur Schulqualität verfasst, in denen auch die Erfassung von Fehlzeiten sowie die verbesserte Kommunikation mit Eltern thematisiert wird. Hintergrund sind nicht nur die verbindlichere Überprüfung schulischer Angebote, sondern zunehmend auch Fragen der Schulwegsicherheit (zeitnahe Information der Eltern bei Nichterscheinen des Schülers bzw. der Schülerin) und Prävention.

Um die Effekte dieser Maßnahmen nicht durch erhöhten Verwaltungsaufwand zu konterkarieren, wird der Bedarf nach integrierten IT-Systemen in den Verwaltungen zunehmen (Breiter & Light 2006; Breiter et al. 2006). In anderen Staaten haben die Prinzipien selbstständiger Schule und die Kopplung von Finanzmitteln an die Leistung der verschiedenen Einheiten (Einzelschule, Schulbezirk etc.) neue Pflichten zur Rechenschaftslegung mit sich gebracht, wodurch die Nachfrage nach IT-Unterstützung schulischer Verwaltungsprozesse sprunghaft gestiegen ist (vgl. OECD 2001). Während in anderen Ländern, wie bspw. Großbritannien, Niederlanden oder in den USA, der Einsatz von Schulverwaltungssoftware bereits flächendeckend realisiert wurde, steht Deutschland in diesem Bereich noch am Anfang. Viele Schulen setzten Software zur Verwaltung von Schülern, Klassenverbänden, Stundenplänen etc. ein. Diese Bemühungen sind jedoch immer noch meist Insellösungen einzelner Schulen. In der Stadt Bremen wurde mit dem Schulverwaltungssystem Magellan schon ein einheitliches System flächendeckend ausgerollt, das auch für die Kommunikation zwischen Schulen und Behörde genutzt wird. Die Länder Hessen und Hamburg setzen auf ein landesweites Informationssystem für Schüler- und Lehrerdaten. Evaluationsergebnisse über die Nutzung liegen bislang nicht vor.

Die Unterstützung von Verwaltungsprozessen durch IT nimmt also auch in deutschen Schulen zu. Die administrativen Arbeiten in Schule sind hierbei vielfältig: vom Inventarmanagement über die Stunden- und Raumplanung bis hin zur Lieferung statistischer Daten über „Schulschwänzer". Im hier vorzustellenden Ansatz geht es vor allem um den administrativen Aufwand der einzelnen Lehrkraft im Klassenraum, sowohl vor, während, als auch nach dem Unterricht.

Selbst an technisch gut ausgestatteten Schulen werden Fehlzeiten, Unterrichtsinhalte und Noten in aller Regel manuell in unterschiedlichen Papiermedien (Klassenbuch, „roter Lehrerkalender" etc.) erfasst. Das Zusammenführen und Auswerten der Daten sowie deren Weiterleitung (z.B. an Schulträger, Schulaufsicht oder Kultusministerium) sind durch wiederholte Medienbrüche gekennzeichnet. Diese Praxis ist nicht nur administrativ ineffizient und für Lehrkräfte und Verwaltungspersonal unnötig zeitintensiv, sie ist auch nicht bedarfsgerecht: Den Schulen und hier insbesondere der Schulleitung stehen die im laufenden Betrieb erzeugten Daten erst mit großem Zeitverzug oder gar nicht zur Verfügung, da die Erfassung stark personalisiert ist. Auch dem extern artikulierten Bedarf nach zeitnaher Information kann nicht entsprochen werden: Beispielsweise wollen Betriebe und Eltern heute umgehend informiert werden, wenn ein Auszubildender bzw. eine Auszubildende oder ihr Kind nicht zur Schule erschienen ist. Um dies zu ermöglichen ist eine zeitnahe Weiterverarbeitung von Daten aus den Klassenräumen notwendig.

2 Datenerfassung im Klassenraum

Auf der Klassenraumebene fallen Daten an, die nach aktuellen Diskussionen für statistische Auswertungen und zur Unterstützung von Entscheidungsprozessen von hoher Relevanz sind. Die Erfassung, Bereitstellung und Nutzung von Informationen für die Unterrichtsorganisation erfolgt aktuell in der Regel papierbasiert und individualisiert. Viele Informationen, wie bspw. Zwischennoten der Schülerinnen und Schüler oder Pläne zur Unterrichtsdurchführung, werden von jeder Lehrkraft individuell z.B. im „roten Lehrerkalender" organisiert. Die Informationen stehen somit auch nur dieser Einzelperson zur Verfügung und sind gegen Verlust unzureichend geschützt.

Der Arbeitsalltag von Lehrkräften zeichnet sich in Deutschland durch eine hohe Mobilität und Autonomie aus. Da Klassenräume einzelnen Schülerverbänden und nicht wie bspw. in den USA Lehrkräften zugeordnet sind, wechselt die Lehrkraft im Laufe eines Schultages häufig die Räumlichkeit. Ausnahmen bilden hier lediglich Fachräume für bspw. Chemie oder Informatik. Zu den Daten, die von den Lehrkräften zu jeder Unterrichtsstunde erfasst werden (müssen), gehören unter anderem die Anwesenheit der Schüler, mündliche Beteiligung und Zwischennoten der Schüler, Hausaufgaben und die Unterrichtsinhalte.

Die analoge Erfassung der Daten macht eine Weiterverarbeitung im Sinne von händischer Übertragung in andere Systeme notwendig. In einigen Fällen geben die Verwaltungskräfte bspw. die Informationen zur Abwesenheit eines Schülers bzw. einer Schülerin in zwei verschiedene Systeme ein. Diese Arbeitsschritte kosten nicht nur Zeit, sondern sind auch sehr fehleranfällig.

Die Umstellung der Erfassung der Daten im Klassenraum von papierbasiert auf IT-gestützt bietet hier einen Lösungsansatz. Digital erfasste Daten können schnell, unter Vermeidung redundanten Arbeitsaufwandes und ohne das Risiko der Verfälschung von Daten an nachfolgende Systeme weitergeleitet werden, so dass sie für die folgenden Prozessschritte zeitnah zur Verfügung stehen. Vor allem der Einsatz mobiler Endgeräte bietet sich hier aufgrund der hohen Mobilität der datenerfassenden Lehrkräfte an.

Von besonderem Interesse ist hierbei die Wahl des Endgerätes, da Lehrkräfte eine sehr heterogene Zielgruppe auch hinsichtlich ihrer Technikaffinität darstellen. Denkbar sind grundsätzlich alle bekannten mobilen Endgeräte mit ihren jeweiligen Vor- und Nachteilen, z.B. Laptop, PDA, Handy/Smartphone oder der digitale Stift. Der entscheidende Aspekt für die Akzeptanz durch die Nutzerinnen und Nutzer ist deren nahtlose Integration in den Arbeitsalltag und der unmittelbare Nachweis der Arbeitserleichterung. Die wechselnde Tätigkeit von Lehrkräften in unterschiedlichen Klassenräumen, auf Exkursionen, Klassenfahrten oder in Projektwochen macht diese Zielgruppe besonders geeignet für „dezente“ mobile Endgeräte. Unter „dezent“ verstehen wir die minimale Invasion in bestehende Alltagsroutinen, eine sehr begrenzte Anlernphase, schnelle Erfolge und eine dauerhafte Verfügbarkeit ohne großen Aufwand.

3 Einsatz mobiler Endgeräte

Im Rahmen unseres Evaluationsansatzes werden lediglich PDA, Handy/Smartphone und Digitaler Stift genauer betrachtet. Der Einsatz von Laptops in Schulen ist bereits vielfältig erforscht, wenn auch mit dem Fokus auf pädagogische Aspekte (z.B. Häuptle & Reinmann 2006; Light 2002; Schaumburg 2003). Im Folgenden wird die Nutzung eines Laptops nicht genauer betrachtet, da die Anforderungen denen einer Desktop-Lösung stark ähneln. Der hier betrachtete Ansatz setzt jedoch auf „dezente“, mobile Endgeräte im Sinne kleiner, leichter und somit einfach transportier- und personalisierbarer Geräte.

Die Nutzung mobiler Endgeräte für Verwaltungsanwendungen durch Lehrkräfte spielt bislang in Deutschland (noch) überhaupt keine Rolle. In anderen Ländern existieren dagegen langjährige Erfahrungen. So wurden in Großbritannien bereits seit den 1980er Jahren IT-Systeme zur Unterstützung der Verwaltungstätigkeit eingesetzt (vgl. Wild et al. 2001), in den Niederlanden werden Schulinformationssysteme auch für die Entscheidungsunterstützung von Leitungspersonal genutzt (vgl. Visscher & Bloemen 1999) und in Neuseeland haben bereits mobile Endgeräte (Handys) inklusive Benachrichtungsdienste für Eltern eine starke Verbreitung (Urbach & Weßler 2006).

Im Rahmen eines Masterprojektes an der Universität Bremen soll deshalb untersucht werden welche mobilen Endgeräte in der Lage sind Lehrkräfte im Bereich der administrativen Tätigkeiten zu entlasten. Die im Unterricht anfallenden Daten werden durch die Lehrkräfte mit mobilen Geräten erfasst und unmittelbar weitergeleitet („digitales Klassenbuch“), so dass sie direkt und in elektronischer Form für nachfolgende Prozesse zur Verfügung stehen. Medienbrüche entfallen, Schulen und Behörden verfügen über eine aktuelle und redundanzfreie Datenhaltung. Ziel ist es die Daten, die aktuell im Klassenbuch und „rotem Lehrerkalender“ erfasst werden zu digitalisieren.

Es kann davon ausgegangen werden, dass die Wahl des Endgerätes für die Lehrkraft einen großen Unterschied in der Akzeptanz und Alltagspraktikabilität ausmachen kann. Im Rahmen des Projektes soll also der Einsatz verschiedener Endgeräte im Kontext Schule erprobt und somit Vor- und Nachteile identifiziert werden.

4 Evaluationsansatz

Da der Einsatz technischer Hilfsmittel für administrative Tätigkeiten in deutschen Schulen noch recht neu ist, sind keine breiten Untersuchungen, sondern nur experimentelle Studien möglich. Es gibt bisher noch nicht genügend Schulen, die solche Systeme einsetzen. Aufgrund der aktuellen Entwicklungen zur Erhöhung der Qualität von Schule und der vermehrten Messungen derselben ist zu erwarten, dass im schulischen Alltag immer mehr Daten erhoben und digital vor allem auch für statistische Zwecke weiterverarbeitet werden. Als Projektpartner wurden zwei sehr unterschiedliche Schulen gewonnen. Zum einen ein Schulzentrum (Klassen 5 bis 13) mit circa 1.000 Schülerinnen und Schülern sowie 80 Lehrkräften. Zum anderen eine private International School mit 200 Schülerinnen und Schülern sowie 40 Lehrkräften. Während die öffentliche Schule sich erst am Beginn einer zunehmenden Datensammlung befindet und die Rechenschaftslegung eher rudimentär und dann vor allem papierbasiert erfolgt, hat die International School bereits seit Jahren ein Schulinformationssystem im Einsatz, das auch das gesteigerte Informationsbedürfnis der Eltern, die hier „zahlende Kunden“ sind, befriedigen muss.

Die grundlegende Methode folgt dem Ansatz der formativen Evaluation (vgl. Flagg 1990; Tessmer 1993), mit deren Hilfe auch die Einbeziehung der Nutzerinnen und Nutzer im Sinne einer partizipativen Systemgestaltung (z.B. Floyd 1993) ermöglicht wird. Bei der formativen Evaluation erfolgt im Gegensatz zur summativen Evaluation eine kontinuierliche Rückkopplung der Ergebnisse an die beteiligten Personen, um bereits im Entwicklungsprozess Maßnahmen zur Reorganisation bzw. Geschäftsprozessentwicklung einleiten zu können. Die hierfür verwendeten qualitativen Verfahren sind vergleichbar zur partizipativen Systemgestaltung, bspw. Interviews im Kontext (Beyer & Holtzblatt 1998), Beobachtungen oder auch Gruppendiskussionen (Rossi & Freeman 1993; Trauth 2001).

Das Evaluationskonzept sieht vor, verschiedene Gruppen von Lehrkräften mit verschiedenen Endgeräten auszustatten und ihren Arbeitsalltag zu beobachten, dabei Interviews im Kontext und abschließend jeweils eine Gruppendiskussion zu führen. Die vier zu betrachtenden Varianten und damit die Gruppen sind:

1. papierbasiert (Kontrollgruppe)
2. PDA
3. Handy/Smartphone und
4. Digitaler Stift.

Je Vergleichsgruppe sind je drei Lehrkräfte vorgesehen. Hierbei soll versucht werden, eine recht heterogene Gruppe (Alter, Technikaffinität, Unterrichtsfächer) zusammenzustellen, um einen verallgemeinerbaren Einblick in positive und negative Effekte der jeweiligen Variante zu bekommen. Dabei wird auf gängige multivariate statistische Analyseverfahren wie Signifikanztests und Regressionsanalysen zurückgegriffen.

Den Testpersonen werden zudem verschiedene Aufgaben gestellt, die sie mit Hilfe der technischen Lösungen bewältigen sollen. Der Nutzungskontext wird hierbei gemäß ihrer bisherigen Aufgaben bezüglich der Datenerfassung im Klassenraum gestaltet. Zu den Aufgaben zählen:

- Erfassung der Anwesenheit inklusive dem Nachtragen von Entschuldigungen
- Notizen zur mündlichen Beteiligung, zum Verhalten und zu den Hausaufgaben der Schüler
- Vermerk zu den Unterrichtsinhalten
- Vergebene Hausaufgaben

Im Rahmen der Evaluation werden die folgenden grundlegenden Qualitätsfaktoren aus der DIN EN ISO 9241-11 zur Gebrauchstauglichkeit als Kriterien durch den Einsatz verschiedener Methoden untersucht (vgl. ISO 1998):

- Unter *Effektivität* wird verstanden wie genau und vollständig das Arbeitsergebnis mit der gewählten Methode erreicht wird. Dieses Kriterium wird im Rahmen der Untersuchung durch Beobachtungen und Interviews im Kontext mit den Lehrkräften untersucht.
- Unter *Effizienz* wird der eingesetzte Aufwand zur Erreichung des Ziels mit der Qualität des Ergebnisses ins Verhältnis gesetzt. Dies wird durch die Messung der benötigten Zeit für die einzelnen Aufgaben erreicht.

- Der Aspekt der *Zufriedenheit* ergänzt die beiden aufgabenbezogenen Kriterien durch die Einbeziehung der subjektiven Einschätzung der Lösung durch den Nutzer. Die beteiligten Lehrkräfte bekommen während der Testphase, durch einen Fragebogen und in Form einer Gruppendiskussion die Gelegenheit ihre Einschätzung der Lösung kundzutun.

Variante →	je 3 Lehrkräfte und verschiedene Aufgabenstellungen			
Kriterien ↓	Papierbasiert	PDA	Handy/Smartphone	Digitaler Stift
Effektivität				
Effizienz				
Zufriedenheit				

Tabelle 1- Evaluationsraster

Der Fokus der Untersuchung wird zunächst auf die Unterstützung aktueller Verwaltungsprozesse und die Auflösung von Medienbrüchen gelegt. Diese Herangehensweise ermöglicht den Vergleich zwischen der aktuellen Arbeitsbelastung und der mit dem jeweiligen mobilen Endgerät. Der Einsatz der Endgeräte kann somit isoliert, unabhängig z.B. von neuen zusätzlichen Auswertungsmöglichkeiten der nun digital vorliegenden Daten, untersucht werden.

Entscheidend ist aus unseren Vorstudien die Zeitersparnis IT-gestützter gegenüber den aktuell eingesetzten papierbasierten Verfahren. Für den erfolgreichen Einsatz von mobilen Endgeräten in Schule ist es notwendig, dass ein Mehrwert in Form von Zeit für die pädagogische Arbeit oder aber ein Mehrwert an Information, die den Unterricht verbessern kann, vorhanden ist. Entwicklung, Betrieb und Einsatz eines solchen Systems ist mit hohen Investitionen und laufenden Kosten verbunden, so dass ein zeitnah absehbarer Return-On-Invest (monetär oder qualitativ) zu erwarten sein sollte.

Die Bewertung erfolgt auf der Basis der bisherigen Verwaltungsprozesse (Workflows) im Vergleich zu den künftigen Verfahren. Hierfür wurden die bestehenden Prozesse in Form von ereignisgesteuerten Prozessketten modelliert, um eine Vergleichbarkeit zur Vergleichsgruppe sowie für die ex ante Betrachtung zu ermöglichen.

Ziel des Systems soll es sein, den Arbeitsalltag von Lehrkräften zu vereinfachen, so dass die Verwaltungsarbeit keinen zu hohen Prozentsatz der Arbeitszeit einnimmt. Ein System, dass von Lehrkräften als „zusätzliche Komplikation“ oder „Last“ empfunden wird, ist nicht zielführend. Daher wird der Schwerpunkt bei den Beobachtungen auch sein, in wieweit die mobilen Endgeräte wirklich „dezent“ in den Arbeitsalltag integriert werden können.

5 Ausblick

Der Einsatz mobiler Endgeräte im Klassenraum und damit zeitnah elektronisch zur Verfügung stehenden Informationen können jedoch nicht nur einen Mehrwert für die einzelne

Lehrkraft sondern auch die Verwaltungskräfte im Sekretariat bedeuten, die bspw. keine Abwesenheiten von Schülerinnen oder Schülern mehr in Tabellen abtippen müssen. Auch der Schulleitung stehen mit Hilfe des Systems, das durch mobile Endgeräte ermöglicht wird, aktuellere Informationen zur Verfügung.

Die Chancen zur Vereinfachung der Prozesse und Entlastung der Lehrkräfte von der immer größer werdenden Forderung nach Daten zur Unterstützung von Entscheidungsprozessen von Seiten der Schulträger oder Kultusministerien ist in Bezug auf Deutschland noch wenig erforscht.

Es wird erwartet, dass der Einsatz digitaler Stifte von den Lehrkräften am positivsten aufgenommen wird. Die Nutzung entspricht weitestgehend ihrem bisherigen Alltag – Stift und Papier. Auch die Individualität der Lehrkräfte kann erhalten bleiben, da das System der Art offen gestaltet werden kann, dass jede Lehrkraft eigene „Tags“ für verschiedene Informationen definieren kann (so wie sie bisher auch verschiedene Zeichen für verschiedene Informationen bspw. in ihrem „roten Lehrerkalender“ nutzen). Das System kann diese individuellen Eingaben erlernen und in die für die weiteren Systeme notwendigen Formate umwandeln.

Der soeben skizzierte Kontext lässt natürlich keine repräsentativen Ergebnisse zu. Es ist jedoch zu erwarten, dass erste Hinweise auf die Akzeptanz verschiedener Endgeräte und den generellen Nutzen derselben für Lehrkräfte in ihrem Arbeitsalltag, festgestellt werden können. Die Betrachtung zweier sehr unterschiedlicher Schulen lässt auch an Stelle der Rolle organisatorischer Aspekte Rückschlüsse erwarten.

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Design Challenges for Wearable Computing

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Abstract

This paper suggests a specific theoretical understanding for the concept of wearable computing. This understanding is inspired by Polanyi's theory of tacit knowledge and is also in line with a number of established theories on human-machine interaction. One way of stating tacit knowledge theory is that the capacity to carry out skilful human activities is at least partially implicit to their performance. The paper argues that the specific potential of wearable computing lies in integrating with such skilful activities and that their tacit character makes for a number of corresponding design challenges. These design challenges and some approaches to address them are illustrated by a concrete design case. Finally, a number of major directions for future research are outlined.

1 Introduction

The potential of wearable computing comes from the possibility to integrate closely with skilful human activities. To explain this specific potential and also the corresponding challenges for design, here is a description of how people use artefacts in skilful activities.

When we use a stick as a probe to explore an unknown area, our perception is that the tip of the stick touches the surface of the objects, conveying to us their general geometry and the texture and consistency of their surface. You can easily try this by probing the objects on your desk with a pen. Despite our sensation, what is actually available to our sensory apparatus is just the pressure exerted by the stick on our fingers. By learning to use a stick as a probe, we learn to interpret these pressure differences in terms of the object qualities we are interested in. This relation is what tacit knowledge theory calls tacit (Polanyi 1967). In the stick case it means that our capacity to interpret the pressure of one end of the stick in terms of object properties at the other end is implicit to performing the probing action. Or put differently, in the probing action we do not know the pressure and its relationship to object properties in an explicit way that we could express as parameters or rules. Tacit knowledge theory does not say that the relationship is principally inaccessible to analysis. It just says that in skilful performance the parts of the relationship are not known analytically but implicitly in the explained sense.

What this means for the use of artefacts in skilful activities is that they are appropriated in a fundamental sense. We learn to use them in the same way that we use the rest of our body. As far as the performatory capacity is concerned the artefacts become part of the body. It is in this sense that appropriately designed technology can be said to become embodied. One example for this understanding is the account of embodied interaction by Dourish (2001) who has also been referring to Polanyi's stick example. Polanyi's theory also offers an important enriching perspective on another theoretical foundation for the design of interactive systems which is Heidegger's distinction between different modes of existence for objects depending on whether they are engaged in our activities. The implications of this theory for the design of interactive systems have been described by Winograd and Flores (1986) in their seminal "Understanding Computers and Cognition: A New Foundation for Design".

Based on this understanding, the potential of wearable computing is therefore to have interactive technologies that people can integrate with their skilful activities and use with the same ease and efficiency they can learn to use their body. In this sense wearable computing may serve as an amplification of human skill and competence as opposed to a partial replacement. This notion is reflected in Mann's "Wearable Computing as means for Personal Empowerment" (1998). What we can also learn from Mann's text is that the potential of wearable computing is quite neutral as to whether we actually will turn it into personal empowerment or rather in an intricate and intimate control structure.

So there are at least two distinct design challenges for wearable computing. The first comes from the tacit nature of skilful activities, including the use of artefacts. This makes it difficult or practically impossible to fully understand a skilful activity in an analytical sense in order to deduce a design for some wearable system. Also, the prospective users cannot fully judge a design other than by integrating it into their skilful activity – a process that is likely to change both the skilful activity and the best fitting design. The second challenge is a long-term corollary of the first one. The tacit nature of skilful activities makes it even more difficult to judge whether a given design will eventually be perceived as an empowering support or as a constraining instrument of control.

It is an obviously important question for the field of wearable computing, whether there are unique design challenges requiring fundamentally different design approaches. I would argue that this is not the case. The theory of tacit knowledge does not only extend to the use of artefacts in skilful activities. It is a general theory of how human beings make use of their cognitive abilities. Unsurprisingly therefore, it has also been used to explain for example knowledge processes in organisations (Nonaka and Takeuchi 1995). This means that the design challenges outlined above apply to all fields of designing information technology for skilful activities. What is specific about wearable computing is that it can be integrated closely with bodily activities, making it particularly difficult to study the context of use and how potential designs could be integrated. Conversely, the full potential of wearable computing can only be leveraged if a good integration is achieved. Design approaches for addressing the principal challenges do exist. So I would argue that the main design challenge for wearable computing consists in studying how these approaches can be applied to the specific design task and also in actually implementing these approaches in real-world development.

2 Design approaches

This section is supposed to tie some important approaches to the design of information technology to the above discussion, not to deliver a comprehensive overview of the approaches.

In his review of Polanyi's "The Tacit Dimension", Alexander (2002) says that the book should be read by every requirements engineer. The reason being that because of the tacit nature of knowledge, users of prospective systems cannot readily express many of their requirements: "Scenario workshops, prototypes and demonstrations are better for that". These techniques and the understanding that they are useful for design are of course not new. They have been part of participatory and user-centred design for many years now (Norman and Draper 1986; Schuler and Namioka 1993).

What is different and difficult about wearable computing is the close integration with bodily activities as explained above. This makes it very different from standard desktop computing and probably still substantially different from mobile computing. As a consequence, techniques for prototyping and demonstrations have to be adapted. For example, the question of device ergonomics is of great importance for the actual usability of wearable systems. An interesting approach for prototyping wearable technologies in a user-centred design process has been developed at CMU (Siewiorek and Smailagic 2002).

One of the particularly difficult consequences of the tacit nature of using artefacts in skilful activities is that it is hard or impossible to anticipate what it will be like to be using new technology in these activities. Whether the technology can be used with ease, whether it is perceived as trustworthy, and whether it is thought to be aesthetically acceptable is a matter of experiencing the technology in use. In order to create this quality of experience early on in the design process, approaches for 'experience prototyping' have been developed (Buchenau and Suri 2000). In order to reproduce the usage situation with a level of authenticity that is meaningful for design, the skilful activities have to be simulated with a sufficient level of engagement and situational richness for the users. This is particularly the case when the activities involve social interaction. An approach that addresses this challenge is game-based design, trying to recreate the usage situation with its interactional patterns in an engaging simulation (Iacucci, Mäkelä et al. 2000).

In a real-world design effort, all of these design approaches are applicable to varying degrees. The following section provides a short overview of how we tried to combine some of these approaches to designing wearable computing in the context of a large research and development project (Klann 2007).

3 Wearable Computing for Fire Fighters – A Case Study

In the context of a 4.5 years research and development project with more than 30 industrial and academic partners, we were tasked by the European Commission to investigate how wearable computing could contribute to an empowerment of the European workforce in the mid-term future. My contribution to this project was to define and carry out a user-centred design approach for one of the 4 application fields of the project, namely emergency response. The primary goal was not to identify a specific problem in this domain and design a solution. The goal, as I see it, was to understand as much as possible the principal challenges to designing sustainable solutions and provide informed guidance as to which design approaches prove most suitable for specific design problems.

This section provides some concrete examples for the design challenges outlined in the first section and describes how we implemented some of the design approaches described in the previous section.

The research on emergency response was conducted in collaboration with the Paris Fire Brigade, with a focus on fire fighting. This domain constitutes a paradigm case for tacit knowledge as explained in the first section. While there are many rules and regulations, the skills of the profession are chiefly acquired in years of exercise and training. And to the extent that this training involves specific operational procedures and specific equipment, the capacity of carrying out the professional work is implicit to the capacity of using this equipment and performing these operational procedures. A substantial part of the skills and expertise resides in using tools in a certain way. A good example for this is the use of the lifeline, a rope that fire fighters use to support indoor navigation under impaired visibility. Experience then may show the boundaries of procedures and tools and may allow seeing alternatives. Nonetheless, the trained skills constitute a certain obstacle towards considering different equipment or procedures.

In our research we worked towards an understanding of the profession through ethnographic studies as well as by actually undergoing part of the training. Primarily, this made us aware of the gap between formal and official rules and what's to be learned from putting the work into practice. Also, it inspired us to target specific questions with specific techniques.

In order to support early requirements elicitation and enable low-fidelity prototyping in an engaging way, we developed a board game for simulating fire fighting interventions. The point about this technique is to reduce the barriers for reflection about new equipment and procedures. This is achieved by putting the participants in a game-like simulation that confronts them with for example challenging situations of breakdown of established procedures. The game-like quality of the simulation as well as the intentionally low-fidelity appearance and ambiguous character of paper prototypes for wearable technologies facilitates reflection on possible alternatives to current practice and equipment. The downside of this technique is the lack of interactivity and poor validity when it comes to device ergonomics.

To address the downside of interactivity we then created a multi-player virtual environment for simulating fire fighting interventions while using interactive virtual prototypes of wearable technologies. As with the board game, this virtual environment also provides an engaging yet playful experience to the participants, facilitating to reflect on designs outside the box of currently established procedures and concepts. The great benefit of the technique is that it allows experiencing new technologies interactively in the context of an immersive and visually realistic environment as well as the social interactions characteristic of their team work. The underlying belief is that such environments can be made sufficiently realistic in order to trigger skilful collaborative activities, such that the corresponding tacit knowledge can be brought to bear on the assessment of the virtual prototypes.

Our current research is on investigating a system we call LifeNet on the support of indoor-navigation (Klann, Riedel et al. 2007). The system consists of a sensor network that is being deployed ad-hoc by the firemen forming a network of interconnected virtual lifelines. This network communicates with a wearable system that provides navigational support on either a head-mounted display integrated with the breathing mask or as auditory commands over a headset. The research interest consists in better understanding how fire fighters handle the difficult task of indoor navigation under impaired visibility and also how navigational information needs to be presented to be useful under these specific circumstances. For both questions, the approach seems promising with respect to the tacit nature of the skill in that it provides rich experiences of using the technology and allows providing feedback through demonstration.

The obvious fallback of the virtual simulation is again device ergonomics. To some extent we try to remedy this by connecting physical prototypes of wearable technologies to the virtual environment once they are available. But obviously, this is not always the case and also it is one of the points of virtual simulations to be feasible before physical prototypes become available. The other drawback is that the situational quality of fire fighting interventions (e.g. heat, exhaustion and real risks) cannot be recreated virtually however immersive the simulation might be. Also, the more effort one puts into making it more realistic, the less it is an agile tool for design.

So, in order to address the drawbacks of device ergonomics and the physical situational aspects of the usage situation, we conduct field tests at the training facility of the Paris Fire Brigade. Nonetheless, while this facility provides a real-life environment and the participants of our studies actually get to move around in their gear, such an environment is still ‘just’ a simulation of an actual intervention. It provides a certain level of realism and thus allows obtaining results of a certain level of validity. This is a principal problem: even if we would get to evaluate our systems during a life intervention we would only get one snapshot of the multitude of possible circumstances. And generally speaking, the effort involved in preparing and carrying out more elaborate studies makes them less likely to happen.

What is really required is an empirically grounded understanding which design questions can be investigated with which technique and to which level of validity. Based on this understanding, appropriate techniques can be used depending on the technology under investigation, the design questions of interest, the specific activities and user studied as well as the current stage of the design process.

4 Conclusions

The design problems and approaches presented in the last section are more or less specific to the domain. The extent to which they are valid for other domains is subject for further research. I consider it an important aspect of user-centred design to be attentive to the specificities of the domain under investigation and not to try and apply standard approaches uncritically. Adapting approaches to the expectations, style and culture of the user group may prove an extremely efficient way to achieve sustainable development.

Nonetheless, some conclusions can be drawn from the presented work that point to important strands for further research.

Practice research. A better understanding of the concrete practices of people is the foundation for good design. While there are a number of approaches for studying practice, the transformatory impact of new technologies on practices still is insufficiently understood. Moreover, practices involving skilful and situated collaborative work are notoriously difficult to investigate in terms of observation and analysis, prompting new investigative techniques.

Experience design. The ability to prototype experiences of new technological concepts and assess experiential quality early on in design processes, seems like a particularly important step to explore and decide between different design directions.

Multidisciplinary Design. Specifically for the field of wearable computing integrated design involving disciplines from electrical engineering, over industrial design to fashion design and many in between seems to be crucial. The close integration of wearable technologies with the user's personal space makes deficits on any level of design disturb the overall appreciation of a system. Multidisciplinary design is extremely difficult to achieve, given the different paces, languages and even cultures of the disciplines.

Living Labs. One of the most beneficial factors to innovation is a sustainable and ecologically valid design process. If a user community can be engaged in an on-going design process with rich participation from both the users and the designers, not only can technologies such as wearable computing be designed in a fitting way but also the social context can evolve to make optimal use of the technology. Living Labs are one concept for creating such sustainable and valid environments for innovation.

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Angepasste Benutzerschnittstellen für das Wearable Computing im Projekt SiWear

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Mobile Research Center Bremen

Zusammenfassung

In diesem Positionspapier werden die grundlegenden Ideen zu einer angepassten Benutzerschnittstelle für das Wearable Computing im Projekt SiWear, gefördert durch das BMWi im Förderschwerpunkt SimoBIT (www.simobit.de) vorgestellt[2]. Neben der Darstellung der Gesamtarchitektur werden die Aspekte der sicheren Kommunikation, die Authentisierung und Zugriffskontrolle, Lokalisierung sowie die benutzbare und der Situation entsprechende Benutzungsschnittstellen dargestellt.

1 SiWear Gesamtsystem

Kern von SiWear ist die Entwicklung einer mehrstufigen Integrationsplattform (Abb. 1), deren eine Komponente die Service- orientierte Wearable Enterprise Plattform bzw. die hinterlegten Arbeitsprozesse sind und dessen zweite Komponente das Wearable- Endgerät mit einer ebenfalls service- orientierten Plattform ist. Das System basiert auf einem gezielten „Push“ von Informationen, um den Nutzern zum richtigen Zeitpunkt am rechten Ort mit der rechten Information zu versorgen und um die Kommunikation der teamorientierten Zusammenarbeit zu unterstützen.

[1] Die Autoren danken dem BMWi für die Förderung im Rahmen des Forschungsschwerpunkts SimoBIT und allen Projektpartnern für die gute Zusammenarbeit.

[2] Förderbeginn: 1.8.2007, Laufzeit: 30 Monate; www.siwear.de

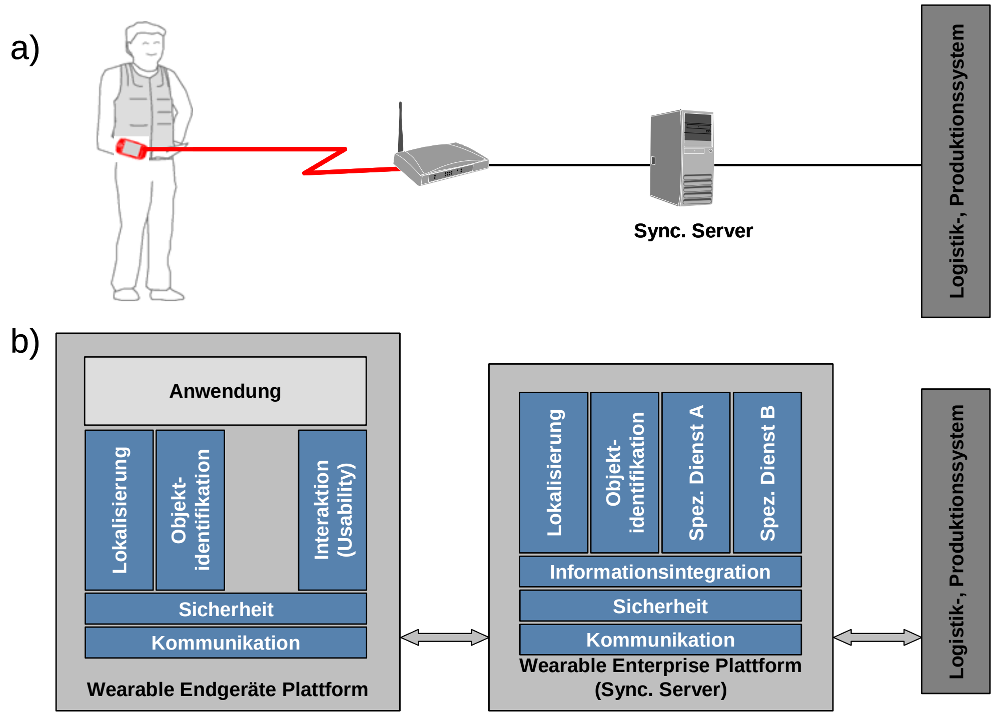

Abb. 1: SiWear Gesamtsystem, a) physikalische Darstellung, b) funktionale Darstellung

Ausgangsbasis sind in einer Anforderungsanalyse identifizierte Arbeitsprozesse und die Modellierung der Gesamtarchitektur sowie Funktionsdemonstratoren zur Evaluation.

Folgende Bereiche werden abgedeckt, jeweils mit dem Fokus auf die Benutzbarkeit und die Sicherheit des Gesamtsystems:

- durchgängig **sichere Kommunikation** zwischen der service- orientierten Plattform und mobilen Endgeräten – Datensicherheit und Datenintegrität,
- **sichere Authentifizierung** der Nutzer und **sichere Lokalisierung** von Nutzern, Objekten und Artikeln
- **benutzbare und der Situation entsprechende Benutzungsschnittstellen** – die eine einfache und konsistente Benutzbarkeit der Anwendung auf dem Wearable- Endgerät erlauben.

2 Sichere Kommunikation

Technologisch wird größtenteils auf vorhandene Sicherheitskomponenten zurückgegriffen wie z.B. (mobile) VPN, WLAN- Absicherung (z.B. mittels WPA 2), GPRS-/UMTS-

Absicherung, Trusted Network Connect-Technologien, Virenschutz für mobiles Endgeräte und Web-Service-Sicherheit. Neue mobile Endgeräte, heterogene Netze und die Forderung nach sicheren, skalierbaren und effizienteren Arbeitsabläufen führen zu völlig neuen Anforderungen an das Service Management von Kommunikationssystemen. Verfahren der Selbstorganisation und der adaptiven Netze sind Lösungsansätze für eine sichere und stabile Kommunikation. In Abhängigkeit der Ergebnisse einer Bedrohungs- und Risikoanalyse und unter Berücksichtigung der modellierten Sicherheitsarchitektur werden somit geeignete Sicherheitsmechanismen adaptiert und bereitgestellt.

3 Benutzbare und der Situation entsprechende Benutzungsschnittstellen

Benutzungsschnittstellen sollen den Anwender bei seiner in der „realen Welt“ auszuführenden Aufgabe unterstützen, indem sie ihm den effizienten, aufgabenorientierten und kontextsensitiven Zugriff auf benötigte Informationen gestatten und die jeweils adäquate Interaktionsform zur Navigation in der Anwendung und zur Datenerhebung zur Verfügung stellen. Die Kommunikation zwischen Nutzer und Endgerät, also die „letzte Meile“ in der Kommunikation zwischen Mensch und IT-Infrastruktur ist sicherzustellen, d. h. auch hier sind Datensicherheit und –integrität zu gewährleisten.

Die Basistechnologien setzen an verschiedenen Stellen der Systemarchitektur an (vgl. Abbildung 2).

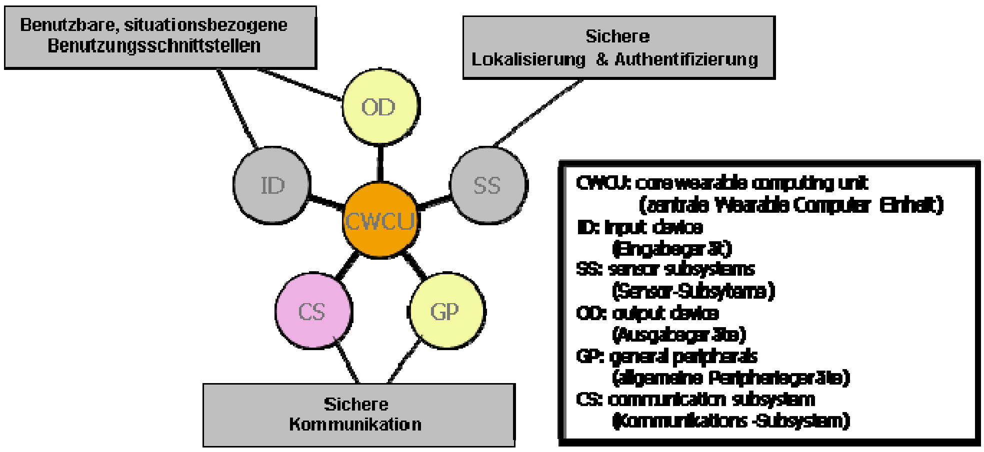

Abb. 2: SiWear Systemarchitektur (basierend auf wearIT@work[3])

[3] www.wearitatwork.com

Die anwendungsspezifische Systemintegration unter Verwendung von **COTS**[4] Komponenten wird in Benutzbarkeitsstudien evaluiert. Hierzu werden aus kommerziell erhältlichen Hardwarekomponenten Funktionsdemonstratoren entwickelt, die erlauben Komponenten und deren Kombination zu bewerten und in Labor- und unter Realbedingungen zu testen. Die Demonstratoren sollen auch für den Test und die Evaluierung der softwareseitigen Anwendungskomponenten genutzt werden.

In Voruntersuchungen wurden verschiedene Komponenten des Wearable Computing auf ihre Akzeptanz bei den Endnutzern untersucht. Vor allem der Einsatz von Head-Mounted Displays (HMD) wird besonders beachtet. Einfache und sehr übersichtliche Benutzerschnittstellen (vgl. Bild 5) sollen die kognitive Last beim Endnutzer reduzieren. Die 1:1 Übertragung von Desktop Benutzeroberflächen ist ungeeignet. Für das Wearable Computing entwickelte Werkzeuge für Softwareentwickler zur Gestaltung ergonomischer Wearable Computing Interfaces sollen eingesetzt werden[5].

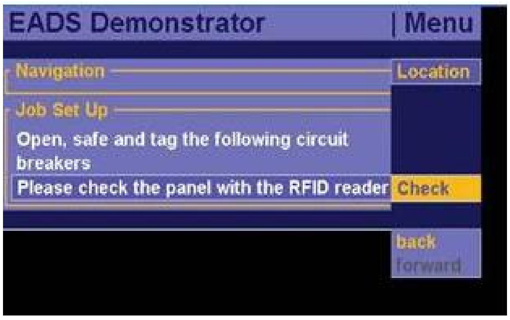

Abb. 3: Beispiel eines geeigneten Wearable Computing (HMD) Interface

Bei der Sprachsteuerung zeigte sich, dass solche Systeme vielfach Schwierigkeiten mit mundartlich gefärbter Aussprache haben. Eine Steuerung über einzelne Laute, wie die Steuerung mittels Gesten über einfache Armbänder oder Handschuhe wird erprobt werden.

Insgesamt wird bei der Einführung von Wearable Computing Lösungen Neuland beschritten. Und so wie es einiger Versuche, Zeit und Übung bedurfte, um beispielsweise die Maus als Standardinteraktionsgerät für graphische Benutzerschnittstellen, den PC im Büro und das CAD in der Konstruktion zu etablieren, sind hier ähnliche Hürden noch zu nehmen, ganz unabhängig von den rechtlichen Fragestellungen hinsichtlich der Sicherheit und Zuverlässigkeit der beschriebenen Lösung.

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[4] Comercial-off-the-shelf

[5] Ernesto Morales Kluge and Hendrik Witt: Developing Applications for Wearable Computers: A Process driven Example. 4th International Forum on Applied Wearable Computing (IFAWC), Tel Aviv, Israel, March 12-13, 2007

Sichere Wearable Systeme zur Kommissionierung industrieller Güter sowie für Diagnose, Wartung und Reparatur

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Zusammenfassung

In diesem Positionspapier werden die grundlegenden Ideen zum Projekt SiWear, gefördert durch das BMWi im Förderschwerpunkt SimoBIT (www.simobit.de) vorgestellt[1]. Neben der Motivation und der Aufstellung des Konsortiums, werden die Problemstellung, der Lösungsweg und die erwarteten Ziele dargestellt.

1 Einleitung

Das Vorhaben SiWear zielt auf einen Durchbruch für den Einsatz der mobilen ‚Wearable' IuK Technologien in produzierenden Unternehmen und dem nachgelagerten After-Sales Bereich. Computersysteme, die während der Nutzung, vergleichbar mit einer Armbanduhr, am Körper getragen werden, bieten die Möglichkeit, Informationstechnologien tiefer in Arbeitsprozesse dringen zu lassen und sie ohne Brüche in die vorhandene Infrastruktur und Prozessunterstützung zu integrieren. „Wearable und Mobile Computing" folgt dem Paradigma, Informationen und Geschäftsprozesse an jedem Ort und zu jeder Zeit verfügbar zu machen, ohne dass die primäre Aufmerksamkeit der Benutzer dem Computersystem gilt (Analogie: Fahrzeugnavigation gestützt auf GPS Signalen im Gegensatz zur stationären Routenplanung).

[1] Förderbeginn: 1.8.2004, Laufzeit: 30 Monate

Das SiWear Konsortium besteht aus zwei großen Unternehmen, einem Forschungsverbund sowie zwei innovativen KMU mit der komplementären Kompetenz Hardware und Software. Eines der Großunternehmen (DaimlerChrysler) stellt mit seinem nachgelagerten Dienstleistungsbereich der Werkstätten das Anwendungsfeld. Das andere Großunternehmen (SAP) ist Marktführer im Bereich Unternehmenssoftware. Diese Projektkonstellation soll für eine weite Verbreitung der Projektergebnisse und Nutzung durch KMU sorgen, sei es als Solution-Provider oder als Anwender der branchen- und herstellerübergreifenden Lösungen, die im Projekt prototypisch realisiert werden.

Mangelnde Nutzerakzeptanz der neuen Wearable-Technologie, unter anderem aufgrund von Sicherheitsbedenken, unzureichende Prozessintegration, sowie Hardwaretechnologien, die den Anforderungen einer Produktivumgebung nicht gerecht werden, sind die Haupthindernisse zur Erreichung der vorhandenen Potentiale. Deshalb soll neben der anwendungsspezifischen Systemintegration unter Verwendung von COTS[2] Komponenten in Usability Studies evaluiert werden, wie eine Steigerung der Nutzerakzeptanz erreicht und die tatsächliche Nutzbarkeit der Systeme in industriellen Anwendungen sichergestellt werden kann. Es sollen für die ausgewählten Anwendungsfelder Kommissionierung sowie Diagnose, Wartung und Reparatur Testimplementierungen von sicherheitstechnisch und organisatorisch effizienten und praxistauglichen Wearable Computing Lösungen entstehen.

2 Problemstellung

In zwei Anwendungsfeldern sollen Lösungen entwickelt und erprobt werden. In den beiden folgenden Abschnitten werden diese beiden Anwendungsfelder beschrieben.

2.1 Anwendungsfeld Kommissionierung

Im Nutzfahrzeug- und Motorenbau werden die relevanten Bauteile an den jeweiligen Montagestationen taktsynchron (Just-in-Time) der Endmontage bereitgestellt. Um diesen Ablauf zu ermöglichen, werden die Bauteile in einem vorgelagerten Prozess kommissioniert. Entsprechend des jeweils geplanten Montageauftrags werden hierzu die zugehörigen Bauteile anhand des jeweiligen Kommissionierauftrages auf Schubwägen zusammengestellt. Dabei durchläuft der Werker mit einem Kommissionierwagen die Regalgänge eines Zwischenlagers und stellt die erforderlichen Bauteile zusammen. Im ersten Schritt des Kommissionierprozesses erhält der Kommissionier zum Beispiel einen Ausdruck mit dem jeweils aktuellen Kommissionierauftrag. Dementsprechend muss der zugehörige Lagerort des in der Auftragsliste beschriebenen Artikels gefunden werden. Wurde das zugehörige Ablagefach des aktuellen Bauteils gefunden, so erfolgt die Auswahl und Prüfung des Bauteils. Nach vollständiger

[2] Commercial- off- the- shelf

Abarbeitung des Kommissionierauftrags werden die zugehörigen Bauteile zur Übergabestelle gebracht und von dort mittels des Logistikzuges zur Endmontage weitertransportiert.

Der Prozess der Kommissionierung könnte wesentlich effizienter sein durch die automatische Zuordnung des aktuellen Kommissionierauftrags zu dem zugehörigen Werker, sichere, konfliktfreie Datenübertragung auf mobile Endgeräte, der Arbeitsumgebung angepasste Bereitstellung mobiler End- und Interaktionsgeräte, die Auswahl angemessener mobiler Interaktionsmechanismen und die mobile Unterstützung des Werkers bei der Suche und Identifikation der zugehörigen Bauteile.

2.2 Anwendungsfeld Service

Aufgrund der immer kürzer werdenden Produktlebenszyklen, der zunehmenden Anzahl an Fahrzeugvarianten und der gleichzeitig steigenden Produktkomplexität ist ein optimierter Prozess im Service und Instandsetzungsbereich (Kfz-Werkstatt) unabdingbar. Die Fähigkeit Fehler schnell zu diagnostizieren und zu beheben, stellt eine wesentliche Anforderung an den Service- und Instandhaltungsbereich dar. Dies ist jedoch nur zu gewährleisten, wenn alle servicerelevanten Parameter mit möglichst fehlerfreier Zuverlässigkeit vor Ort verfügbar und verarbeitbar sind.

Für den Werkstattmitarbeiter müssen die relevanten Service-Unterlagen, Diagnose-Verfahren sowie das Wissen bezüglich der Bedienung und Auswertung der Test- und On-Board- Diagnose möglichst einfach zugänglich sein. Neben der mobilen Bereithaltung der Information sind zudem die Bedienerführung sowie die Auswahl geeigneter Interaktionsgeräte von entscheidender Bedeutung. Zu berücksichtigen sind als Teilaspekte die gezielte Informationsaufbereitung der relevanten Service- und Diagnoseinformationen, die Bereitstellung einer Kommunikationsinfrastruktur für den Abruf der relevanten Daten, die sichere, konfliktfreie Datenübertragung auf mobile Endgeräte, eine der Arbeitsumgebung angepasste Bereitstellung mobiler End- und Interaktionsgeräte sowie die Auswahl angemessener mobiler Interaktionsmechanismen.

3 Lösungsweg

Auf der Basis vorhandener Systeme (Hardware und Software) werden Systemlösungen erstellt und erprobt. Eine offene vierschichtige Hardware-Systemarchitektur sowie ein offenes Wearable Computing Software Framework werden seitens der Technologie als aus dem EU IP wearIT@work (www.wearitatwork.com) übernommen.

3.1 Sicherheitsarchitektur

In der Fertigungs- und Prozessdatenverarbeitung werden die drahtlosen Datenübertragungstechniken wie Trusted Wireless, Bluetooth und WLAN immer wichtiger. Die Integration der sehr flexiblen und innovativen Funktechnologien erfordert eine neue Sicherheitsarchitektur, damit zum einen die Daten nicht mitgehorcht (Spionage) und zum anderen die Kommunikationswege nicht so leicht gestört (ungewollte Störung oder Sabotage) werden können. Neben der drahtlosen Datenübertragung werden auch Technologien zur Kontexterkennung (context awareness) eingesetzt, um Objekte schnell maschinenlesbar erkennen zu können. Im Projekt wird die innovative Verknüpfung der etablierten mit den neuen Kommunikationstechnologien in der Sicherheitsarchitektur berücksichtigt.

Das mobile Endgerät hat aus Sicht der Kommunikation die Aufgabe, mit dem Backend zu kommunizieren und Elemente der Kontext-Identifizierungssysteme, wie z.B. RFID-Tags, auszulesen. Um hier einen versehentlichen Gebrauch oder auch eine absichtliche aber nicht erlaubte Nutzung zu verhindern (Autorisierungskonzept), authentifizieren sich Nutzer beim Backend. Zusätzlich wird sich das mobile Endgerät (Gerät nicht Nutzer) beim Backend als „vertrauenswürdig“ authentifizieren. So wird sichergestellt, dass das mobile Endgerät befugt ist, auf das Backend zuzugreifen und das es die vereinbarten Sicherheitsrichtlinien erfüllt. Durch eine verschlüsselte Datenübertragung zwischen dem mobilen Endgerät und dem Backend sowie zum Kontexterkennungssystem wird die Funkstrecke gegen Mithorchen (sniffing) und Datenmanipulationen (Datenintegrität) gesichert.

4 Projektziel

Der Schwerpunkt liegt auf der Erarbeitung von Software- und Interaktionskonzepten, die in ein umfassendes System integriert werden. Kern wird deshalb die Entwicklung einer mehrstufigen Integrationsplattform sein, deren eine Komponente das Backend-System bzw. die hinterlegten Arbeitsprozesse sind und dessen zweite Komponente der mobil tätige computerunterstützte Mensch ist. Es werden Konzepte entwickelt für den gezielten „Push“ von Informationen, um den Nutzern zum richtigen Zeitpunkt am rechten Ort mit der rechten Information zu versorgen und um die Kommunikation der teamorientierten Zusammenarbeit zu unterstützen. Bestehende Abläufe sollen mit SiWear effektiver gestaltet werden z.B. durch die Bereitstellung interaktiver kontextabhängiger Information aus verschiedenen Quellen mit optionaler Dokumentation der Nutzeraktionen, die Bereitstellung und Aufnahme von Erfahrungswissen zur besseren Unterstützung der Arbeitsprozesse und eine Erhöhung der Verfügbarkeit bestehender Systeme z.B. indem jede Person durch ein mobiles Endgerät auf diese zugreifen kann. SiWear wird die Kommunikation innerhalb und zwischen Personen kooperierender Arbeitsgruppen unterstützen. Während der eigentlichen Aufgabenerfüllung werden gezielte Hilfestellungen gegeben, z.B. bei der Durchführung kleinerer ungeplanter Maßnahmen. siWear wird die örtlich und zeitlich präzisere Lokalisierung von Personen, Objekten und/ oder Artikeln, z.B.durch integrierte WLAN und / oder RFID- Technologien (Beachtung datenschutzrechtlicher Fragestellungen und betrieblicher Vereinbarungen) ermöglichen. Die Arbeitsbelastung wird reduziert z.B. durch Informations-, Kommunikations- und Dokumentationsunterstützung sowie durch ein „beiläufiges“ Interaktionsmodell. Schließlich wird die Sicherheit durch systemseitige Hilfen in kritischen Situationen erhöht, z.B. durch unmittelbare und individuelle kontextabhängige Bereitstellung von Prozeduren für den Nutzer.