Changes of HCI Methods towards the Development Process of Wearable Computing Solutions

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Abstract. Logistics is a dynamic and heterogeneous application area for wearable computing. In this paper, wearable computing technologies are examined as basis for a support system for mobile workers at an automobile terminal under the new paradigm of autonomous controlled logistics. An appropriate wearable computing system has to fulfil different system requirements with respect to the mobile work process and the bodily conditions of the user. Therefore the requirements of wearable computing systems were defined in a participatory process with the users.

Keywords: Autonomous Control, Logistics, Mobile Usability, Mobile Work Process, Requirement-Monitoring, User-Centred Design, Wearable Computing.

1 Introduction

In the development of wearable computing solutions impressive progress has been made in the past years, especially for the use in professional business segments [1], but the breakthrough into the market has clearly fallen short of expectations. Here is an intensive study which has attempted to systematically research the innovation barriers and problems of the acceptance of mobile solutions in a broad scale technology analysis and technology assessment study, in order to trace the technical shortcomings of the components available till now, as well as the system deficits of realised applications [2]. The emphasis laid on the usability in the working world beyond the desktop. A stocktaking of technical components and realised systems was carried out, which was checked against the requirements of the potential application areas. On this basis, further configuration recommendations and methodical deductions were submitted.

This study led – amongst others – to the conclusion that wearable computing components require a standardization which would have to be similar to the manufacturing systems and especially to the serial manufacture of clothing (e. g. workwear), since the user will wear it directly on the body. Deriving from this specific bodily stipulation is the thesis that acceptance is a crucial success factor for wearable computing solutions, and the assumption that acceptance can be achieved by a stricter application of Human-Computer-Interaction (HCI) methods, as well as by adapting

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these methods to the special conditions of mobile work processes and wearable solutions [2] One new approach is “using technology as a hands-on experience”, i. e. the early creation of “demonstrators” (mock-ups and prototypes) and their repeated use as a graspable basis for a participatory design dialogue [3]. This approach is being analysed using the example of developing a support system for mobile workers at an automobile terminal under the new paradigm of autonomous logistics control.

Until now, planning and control of logistic processes at automobile terminals were generally executed by centralized logistic systems, which could not cope with the high requirements needed for flexible order processing due to increasing dynamics and complexity. The main business processes at automobile terminals are planned and controlled by centralized application software systems. To deal with the increasing complexity, an innovative approach to autonomous control in automobile logistics is being studied [4]. The general idea is to develop decentralized and heterarchical planning and controlling methods – in contrast to existing central and hierarchical aligned planning and controlling approaches [5]. This research was supported by the German Research Foundation (DFG) as part of the Collaborative Research Centre 637 “Autonomous Cooperating Logistic Processes – A Paradigm Shift and its Limitations” at the University of Bremen (SFB 637) [6].

2 Characteristics of Wearable Computing Solutions

A wearable computing solution can be defined in several ways. Some of them depend on the research direction and on the application domain, most of them try to distinguish it from palm-top applications. Bradley J. Rhodes focuses on the features of the hardware: “wearable computers have many of the following characteristics: Portable while operational (…). Hands-free use (…). Sensors: In addition to user-inputs, a wearable should have sensors for the physical environment (…). "Proactive": A wearable should be able to convey information to its user even when not actively being used (…). Always on, always running (…)” [7]. The wearIT@work project focuses on the interaction between the user, the system, and the environment [1] and defines the basic idea as follows [3]: Computer systems integrated with clothing support their users in an unobtrusive way. They allow the users to perform their *primary tasks* with the assistance of a computer, but without cognitive overload. Explicit interactions with these systems have to be reduced to a minimum. Therefore, the worn system must recognise the current environment and the work situation of a user by integrated sensors. Based on the detected work context, the wearable computing solution has to push useful information to its user, e.g., how to proceed with the work by reducing probable options to a minimum. It allows the user to simultaneously interact with the system and the environment.

Components of wearable computing solutions are Ultra-Mobile PCs (UMPC) and so-called “wearable computer”, head-mounted displays (HMDs), arm-worn keyboards, speech input and output, and wireless connections, as well as different types of carrying and fastening systems, amongst others vests and gloves especially developed for this purpose and augmented with technology. The stocktaking shows, that most of the documented wearable computing solutions are prototypes which serve as feasibility studies for research approaches or field studies [2]. There are hardly any products available to date. Comparing the application areas with the proposed wearable computing solutions made obvious why market penetration has not been yet achieved: The technology is neither adapted to the mobile workers, nor to their primary task beyond "computer work".

3 Characteristics of Mobile Work Processes

To achieve the required adaption, a competent conception of the term *mobile activity* or more specific *mobile work process* is essential. It is the prerequisite for understanding the particularities wearable computing solutions have to cope with when they have to be implemented, in order to open innovation potentials for working processes and to satisfy new application areas.

Assuming that activities are always performed by humans work activities are differentiated into two categories: work processes which are performed at a desk or a stationary workplace, and those which are performed in motion. The centre is the working person who has acquired knowledge and skills, who has an individual style, as well as habits and experiences, who uses tools and materials, requires information on site, who has to take measurements or record her/his work steps during her/his work process and while in motion. Mobile work processes have some common characteristics[1]:

- Performed in motion, e.g. road inspection,
- performed at different locations, e.g. industrial plant maintenance, or
- performed at one location but on varying and big or extensive objects, e.g. inventory management.

It is characteristic for mobile work processes beyond desktop work that the user's primary task and therefore her/his attention is focused on the real world. Furthermore, most mobile work processes are embedded in a more complex work process, which implies a certain level of autonomy of all entities (men, artefacts, and infrastructure) and requires a high degree of communication and cooperation between them.

However, generalizing requirements for wearable computing solutions is not possible; since the various application areas present very differing conditions of utilization which themselves require the use of different technological artefacts [2]. Therefore, the process of developing wearable computing solutions and of HCI interfaces for these technological scope is characterized by an interdependence of the components; i. e. a decision at one point has far-reaching effects, possibly on all components (see fig. 1).

At the highest level, mobile work processes require "mobile assistance systems" that can be worn on the body and that behave like a (human) assistant, e.g. a sub worker or a tutor. Therefore, wearable computing solutions are characterized as "unobtrusive", they are to be used "casually". They are to *dis*burden the user rather than to be a burden. Their use has to be simple and should not require special attention for the user interface, so ideally the user performs her/his "actual" task while at the same time the "computer work" runs automatically. The central source for the concrete requirements for an appropriate mobile assistance system is always the application area and the conditions of use (including the course of movement of the user). Their specialities determine the characteristics of the entire solution.

[1] For the complete scope of human activities and work processes see [2].

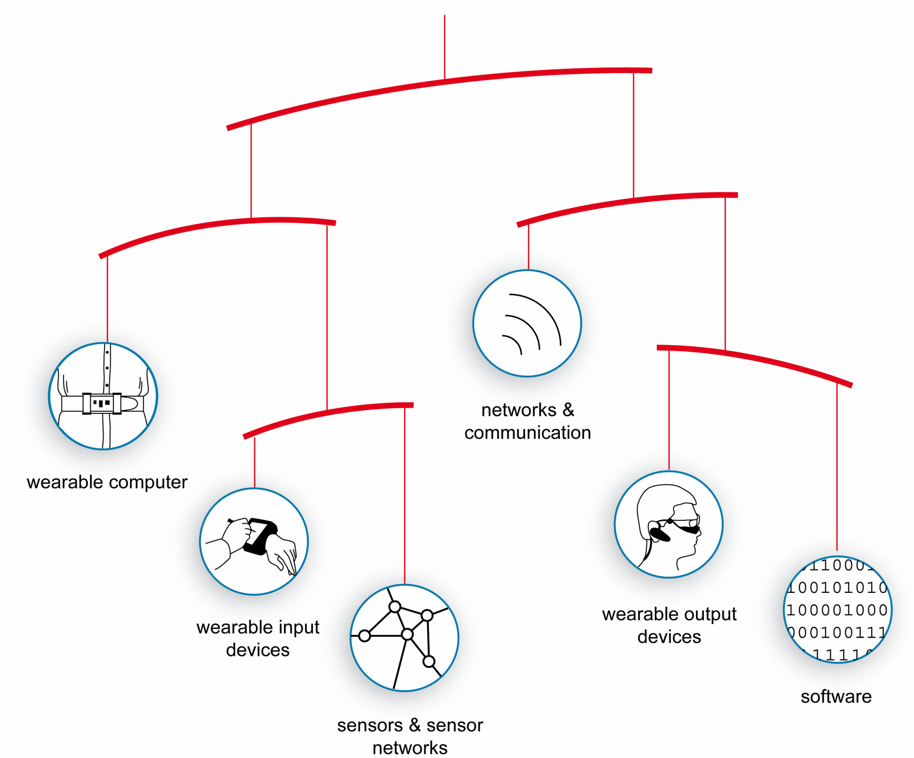

Fig. 1. Dependencies of the components of wearable computing solutions [2]

Most of the wearable computing solutions implemented so far have failed. The reasons are manifold, on an abstract level they conform to the points of criticism already raised by the usability research on desktop computing solutions (see i.e. [8], [9]), but there are also some other problems. There has already been research on usability [10] and wearability [11] but it also failed because of the human-computer interface. One basic mistake, which keeps reoccurring in the development of technologies, is the technology-centred perspective on the solution. Technologies are developed, which from the engineers' point of view are important and useful for the implementation of a mobile solution, without first identifying the intended users' requirements and without letting the prospective users participate in the development.

Generally, the technological approach to wearable computing solutions is not a problem. Actually, technological competence is an essential requirement for the development of complete systems. However, knowledge of the conditions within the application area and of the involved mobile workers is the crucial factor for the achievement of developing wearable solutions.

4 Design of Wearable Computing Solutions

A technology that gets this close to a person's body has to be tailor-made to optimally fit the wearer and their current task – which is always given in the case of tools or clothes, but not for information and communication technology (ICT). But the acceptance of wearable computing solutions is closely linked to the user's appreciation of the entire equipment used (incl. wearing systems and interaction concept). In order to design usable wearable computing solutions, development and evaluation processes need to be improved on several levels (see fig. 2).

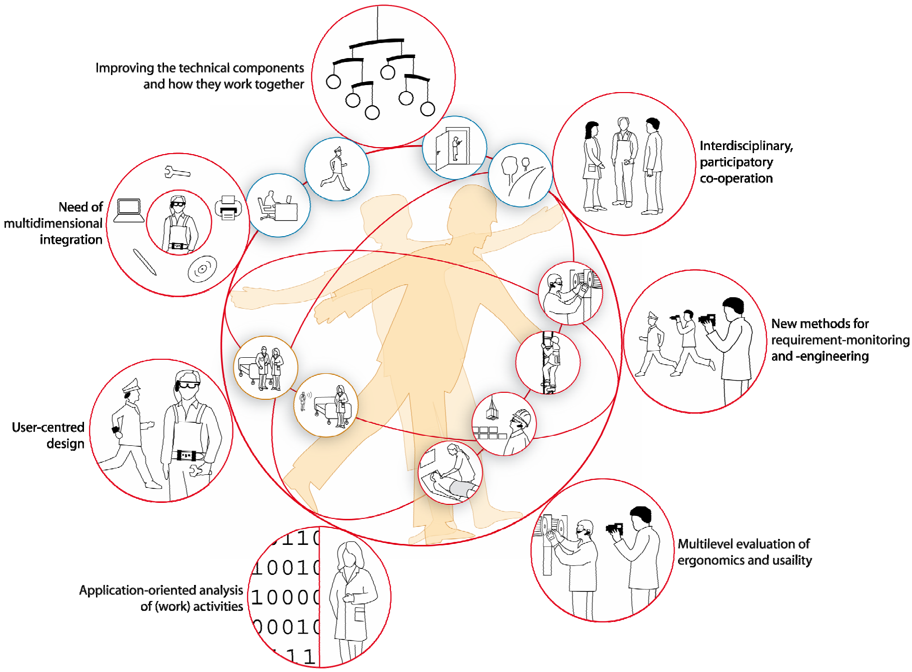

Fig. 2. Essential aspects for the development process of wearable computing solutions [2]

One very important aspect is the methodological approach at the HCI level: Until now, there are not any appropriate methods to record mobile data of mobile work processes for requirement monitoring and analysis. Additionally, most of the known usability testing methods are static, they have been developed for testing ICT used for work processes like desktop work and not for the evaluation of mobile worn technologies for mobile work processes with their dynamic changes of environmental conditions and the motion sequences of the user. To deal with mobility and wearability, additional dimensions have to be taken into consideration for requirement-monitoring and -engineering and also for usability testing. One approach to overcome these restrictions is to use recent wearable computing technology as a hands-on experience with the goal to improve the participatory design process. The basic idea is to use concrete artifacts in real work environments as "graspable arguments" for the dialogue between developers and users. The following example of a real world scenario will illustrate the method.

5 Potentials of Autonomous Control in Automobile Logistics

This paper focuses on the development process of a wearable computing solution for supporting the mobile work processes at an automobile terminal. An automobile terminal develops and provides complex services for new and used vehicles in the range of transport, handling, technical treatment and storage management (for the process see fig. 3).

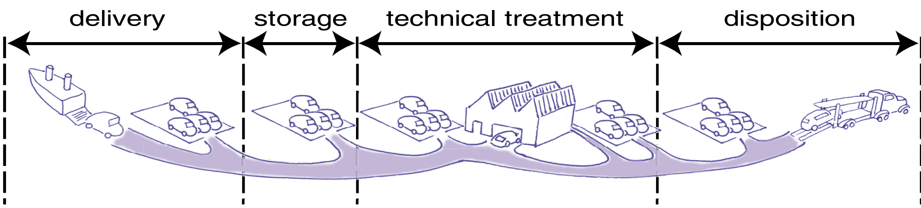

Fig. 3. Business process at an automobile terminal

After delivery, each vehicle is identified by its vehicle identification number (VIN). The VIN allows an assignment of the vehicle to its storage and the technical treatment orders to be stored in the logistic IT-system. A handling employee moves the vehicle to the assigned storage location. After removal from stock, the vehicles possibly pass through several technical treatment stations e.g. fuel station or car wash. The sequence of the technical treatment stations is specified in the technical treatment order of the vehicle. On completion of all technical treatment tasks, the vehicle is brought to the disposition area for transportation to the automobile dealer [12].

The described storage management of vehicles at automobile terminals provides potential for improvement. The storage management is executed by a centralised planning and control system. In case of this, there is no flexible allocation of storage areas and locations considering future process steps or an immediate reaction to disturbances during order processing possible [13].

To realize the potentials for improvement a decentralized and heterarchical planning and controlling method was developed under the paradigm of autonomous control [4]. The idea is to support autonomous logistics with wearable computing technologies. This vehicle management in automobile logistic networks needs knowledge about the positions of all vehicles within the system at a given time. Only high transparency of all vehicle movements in this logistic network allows an efficient disposition of available resources at and between the automobile terminals. With wearable computing systems the needed information can be recorded directly during the working process so they can immediately be accordingly adapted. The future process steps will be planed depending on the actual storage locations and the technical treatment order of the vehicles and the stock capacity and the technical treatment stations. For these goals a wearable computing system and mobile technologies are being developed to support the terminal staff.

6 Requirement Analysis for a Wearable Computing Solution in Automobile Logistics

Objective is the development of a wearable computing system for the mobile work process at an automobile terminal under the paradigm of autonomously controlled logistics. An appropriate wearable computing system has to fulfil different system requirements. Therefore the first step was to define the requirements of wearable computing systems. The requirement analyses was divided into 6 steps (see fig.4).

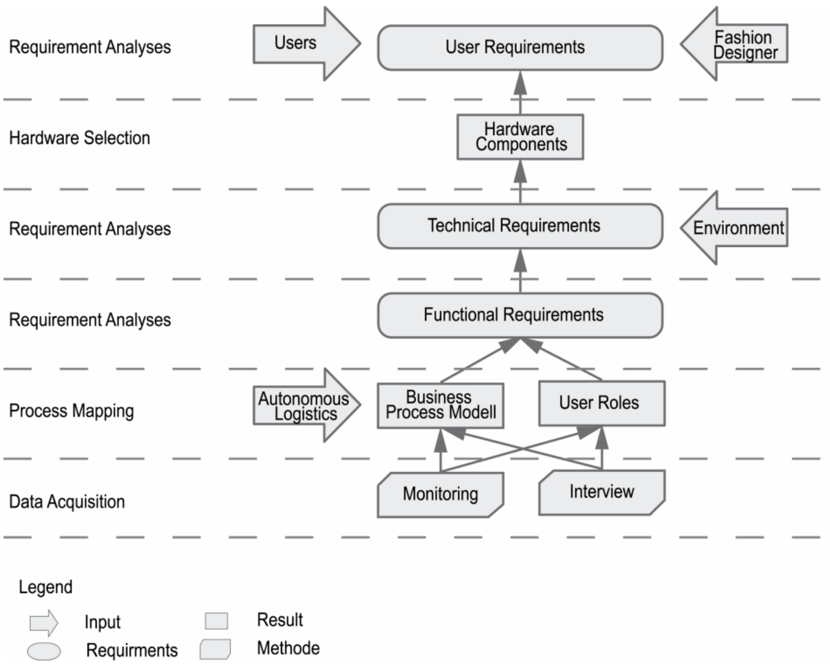

Fig. 4. Process of the analyses of the requirements

The information about the processes at an automobile terminal was gathered by interviews with the end-users and by monitoring the processes. On the basis of this information a business process model was built up, although the user roles were defined and adjusted with the business process model. Based on a decentralised controlled storage management of vehicles, functional requirements were derived from the planned processes for vehicle handling [5]. As mentioned above the vehicle identification by vehicle identification number (VIN) is necessary. The exact position of vehicles at the terminal area is needed in order to realize fast, flexible and orderly storage management. The wearable application has to support the handling employee by user guides or wizards to avoid misunderstandings. The defined functional requirements are based on the business processes and have to support the user who executes the logistic processes.

The technical requirements depend on the environment and on the functional requirements of the operational process. Technology requirements at an automobile terminal are determined by the environment and the necessarily used time. A power management is needed that reduces the energy demand for the operational time which depends on the business time in the operational process. Furthermore it is necessary to design the wearable computing solution to be robust and shock resistant to avoid damage in case of dropping. The system has to be so powerful that it is able to guarantee short response times for executing commands to reduce waiting times in the workflow. Based on these requirements and the functional requirements further technical demands on the hardware were defined. Assuming all these requirements the hardware components were selected. The technical requirements and in result the selected hardware directly affect the usability of wearable computing systems.

7 Implementation of the Wearable Computing System

The operating mode of the individual components was explained to the end-users in a collective "hands-on technology" workshop. This helped to define the users' requirements on the technical components. User requirements like the design of the graphical user interface (GUI), physical dimensions of the system, keyboard design and display quality have direct influence on the user's acceptance. They have been developed in a participatory process with the handling employees. Different wearable displays and GUIs were presented to the end-users. In this process, requirements like the GUI, the viewing distance, and an option for good readability in darkness were defined. The demand for hardware that represents no health hazard is guaranteed to users by the compliance with radiation standards [14], [15]. A fashion designer is developing with the users the design of the workwear for the wearable computing system.

The primary user in the described mobile work process is the handling employee, who moves the vehicles at the automobile terminal between storage locations, technical treatment stations and disposition areas. For this user in the project the use of the "smart jacket" has been designated. The smart jacket is a wearable computing system, which integrates technical components for identification, localisation, communication and user interaction tasks into workwear. The smart jacket includes a Ultra-High Frequency (UHF) RFID module for tag identification, a combined GPRS (General Packet Radio Service) / GPS (Global Positioning System) module for communication and localisation, a Thin-film Transistor (TFT) display with touch screen, hand free audio hardware for user-interaction and a proximity sensor for detection. All components are handled by a central software platform integrated in an embedded microcontroller. The smart jacket enables the basis for decentralised decision-making in autonomously controlled logistic systems. For the other roles on the terminal, the use of mobile technologies like a mobile data entry device (MDE) and a tablet PC is planned.

8 Usability Testing of the Smart Jacket

The first evaluation step of this wearable computing solution will be to check the operational reliability and usability of the smart jacket prototype in a laboratory environment. After implementing these results into a second prototype, the evaluation takes place in a field test in cooperation with the handling employees. In doing this, the general wearability of the system is tested by the end-users, as well as the applicability of the system in the intended operational environment. Based on mobile collected information the wearable computing system is going to be improved until it reaches the user's acceptance.

In the recurrent dialogue between users and designers, the technological artifacts serve as a communication tool as well as instances of the intended wearable computing solution. In the different evaluation phases the roles of the members of involved groups change: sometimes the user and sometimes the technology developer is the expert.

9 Summary and Next Steps

In this contribution, the specific needs of mobile work processes have been compared with the characteristics of wearable computing solutions on a general level. It has argued for changes in the approaches of requirement engineering and usability testing with regard to mobility and wearability. The proposed changes were shown by way of an example of developing a mobile supporting system for handling employees at an automobile terminal under the paradigm of autonomous control. The development of a smart jacket is still in progress and will be evaluated by means of the concept of "using technology as a hands-on experience" (see [2, p.290]).

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