

Authentic User Tests in Industrial Wearable Computing Applications

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Abstract. Wearable computing means a paradigm shift: instead of working at the computer users are supported by computing systems in their primary tasks. Currently wearable computing is still a technology of niches and in a laboratory stage. However, with wearIT@work a 4 ½ years project dedicated to wearable computing applications in industrial settings was launched by the European Commission. The first 30 months of this project are over and industrial demonstrators, evaluations and results are available. Results from user tests in two of the four application domains, namely production and maintenance, based on a newly designed wearable user interface are presented here.

Introduction

wearIT@work [1] is a European Commission-funded Integrated Project to investigate “Wearable Computing” as a technology dealing with computer systems integrated in clothing. The project has 43 partners, among them EADS, HP, Microsoft, SAP, Siemens, Skoda, Thales and Zeiss. With a project volume of 23.7 million € and a funding of 14.6 million € under contract no. 004216, *wearIT@work* is the largest project world-wide in wearable computing. In the literature the background of the project [2] and first results [3] are described¹.

The second phase of the cyclic development approach dealt with several technological experiments selected during this phase and with the implementation of realistic demonstrator prototypes in the application fields of the project. Each of the demonstrators is implemented according to the requirements set by the projects application partners for the respective scenario.

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Platform and Framework

Although the application domains and their requirements vary quite a lot the project aims to have an open wearable hardware platform (OWCP) and software framework (OWCF) to allow for standardization. As a software infrastructure the OWCF supports the construction of domain specific applications for wearable devices. It is a tool used by all *wearIT@work* demonstrators. During the conceptualisation phase guidelines have been set up to simplify the software development process, to encourage reuse of software components across different applications, and to promote better software engineering practices. The definition of the framework requirements took place based on a continuous analysis of end-user requirements.

The spring framework² was selected as the core of the OWCF to minimise demand on resources, because of its minimal invasive effect on components, and the related inversion of the control design pattern. It allows for configuration not only of configuration parameters but for the configuration of dependencies among components, too. Currently parts of the Framework are available as a .Net implementation in MS-Windows environments, other parts as a Java implementation for Linux platforms.³ After design, development, test, and release of the framework components training and support of pilot application developers was performed. The OWCF is ready for take-up by interested parties and contained in the *wearIT@work* software repository⁴.

Application

In **automobile assembly** the partner of the project is the car manufacturer Skoda with five factories in the Czech Republic. As final assembly tasks are complex and manual all Skoda workers receive training at the so called Learning Factory, part of the Skoda factory in Vraclabi. Theoretical training at the 'e-Learning Institute' and practical training at the 'Learning Island' is performed. Approximately 5 to 6 hours training of the worker is today required for this task by an experienced trainer. The goal is to support the training at the Learning Island by further integrating the theoretical training into the practical training and at the end integrated at the assembly line directly. For this two demonstrators supporting training on the final assembly of the front light of a Skoda Octavia were developed, evaluated, refined and integrated to a unique demonstrator after the first of four innovation cycles of the project. One demonstrator was focusing on usability aspects of the solution like the use of textile keyboards and speech input. The second was focusing on automatic task recognition using a sensor network [4] performing event-based activity tracking experiments to achieve automatic context detection [5]. A result of these studies was that both solutions could be integrated. In particular the wizard of Oz based experiments were further developed integrating wearable computing platform components for the wearable

² See <http://www.springframework.org/> accessed 25.10.2006.

³ At the end of the project (late 2008) a full implementation on both platforms is planned.

⁴ See <https://wiaw-file.informatik.uni-bremen.de/svn/wiaw> accessed 25.10.2006.

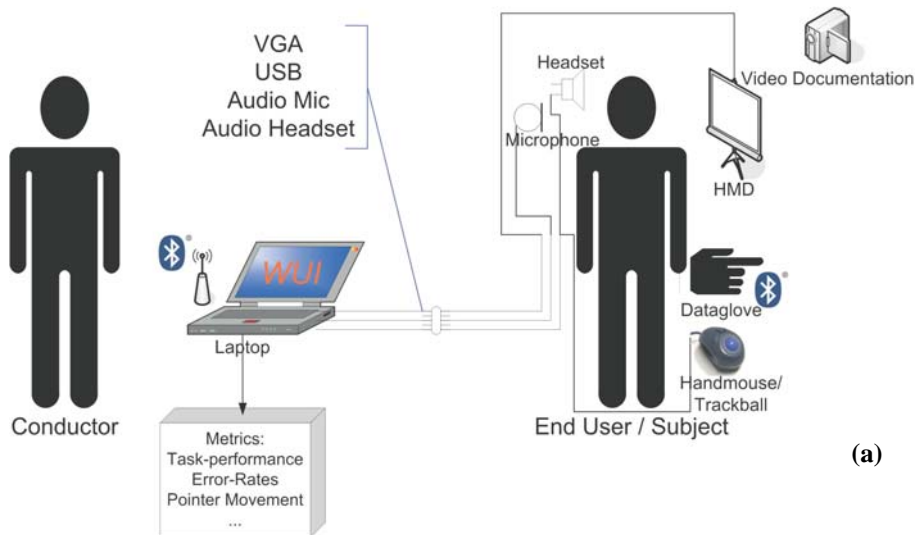
user interface and the context detection. The task recognition system was improved by reducing the number of sensors necessary. Nevertheless some sensors built into the car body are still necessary.

To evaluate the productivity of the solution usability experiments have been performed comparing different input and output devices like monocular look through and look-around displays, binocular head mounted displays, a wall mounted screen and paper. The task performance and the learning productivity were evaluated in a setting dealing with the assembly of mechanical parts and some cable connection in a 3D assembly environment. Experiments with 46 assembly workers have shown that in the test environment assembly instruction by paper being the faster, less erroneous and the easier to learn instruction method compared to the use of a wearable computer. However, when instructing the user with context information similar productivity could be achieved compared to using paper based instructions. The use of keyboards and voice information compared to the wearable computing solution produced worse results. Additionally in the case of context support the learning effect is comparable to the paper based approach [6]. What's more the possibility of implicit documentation, enhanced quality and documentation of the assembly process with a minimum of additional effort was seen as an advantage of the technology. The results of these usability studies became part of the enhanced solution with improved human computer interfaces based on the framework using the context detection and wearable user interface modules for gesture and speech interaction with increased robustness [7].

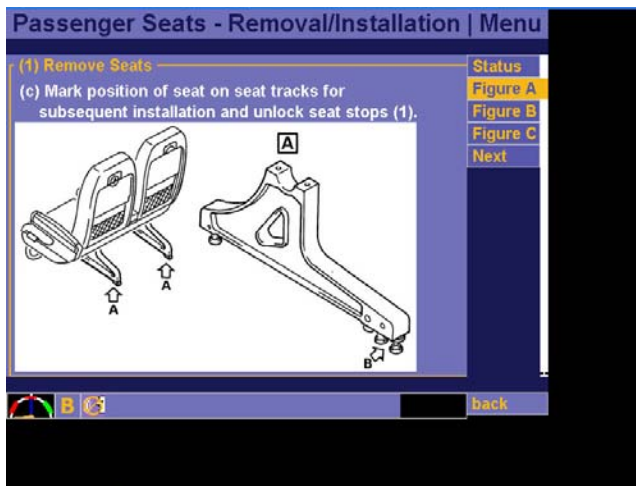
In **aircraft maintenance** design workshops, tests and interviews with the different stakeholders covering technological, economical, social and ethical aspects have been performed at Aircraft Maintenance Service Centres in France and Germany to ensure the solution meets the needs of the workers. Experiments with different user interfaces were done: The input by a track-ball finger mouse was compared with input using a data glove and speech input (see figure 1a). As feedback to the voice and different visual output modalities like text, drawings, photographs and videos were tested and evaluated. The tests and interviews have been performed with a group of 30 people of male and female German maintenance personnel, technical and non technical persons with an academic background of different age and working experience.

The experiments have shown voice input being the most ineffective method when initiating a command. Input by a trackball was a little more effective as input by the data glove. It has to be considered the trackball being a well known input device, but does not allow hands-free operation. Voice input was in so far problematic as the instructions are in English and the German accent created problems. Exceptions were female candidates with a higher language education. Less computer experience was also an advantage when using the glove. In a second trial a wearable computing solution was developed with a special vest and an OQO connected to a Microoptical SP6 display. The OQO was connected by a Bluetooth interface to a refined version of a glove with an RFID reader for identification purposes. As an application the removal of seats was chosen (see figure 1b). - There exists a great many of diverse kinds of seats with different fixtures requiring special purpose tools for removal. The specific information is supplied by the RFID tag on the individual seat and displayed depending on the expertise of the user. The wearable device supplies the operator with guided, context-controlled access to the aircraft maintenance manual, with hints about

steps to be performed and with more extensive advice, if necessary. There has been a positive reaction by the maintenance personnel accepting there is a more efficient and easier workflow.



(a)



(b)

Figure 1: Initial laboratory experiment to find best input and output modalities for aircraft maintenance worker (a) which later on results in a user interface design compliant with experiment results (b).

In interviews workers expressed their concern about becoming overly dependent on the wearable. They recommended a back up of printed manuals and checklists, and the periodical re-training of in-depth procedures. Collaboration by wearables could

improve efficiency and autonomy as well. Face to face communication would still be necessary. Physical interactions and contact should be retained and promoted. Operators emphasized the need for training and support when the system is introduced. To avoid disabled, e.g., hearing impaired workers to be limited to use wearables, disabilities should be considered already in the design phase [8].

Conclusion

In this paper we present intermediate results from two industrial case studies in automotive production and aircraft maintenance. In a cyclic user-centred design approach within two innovation cycles usability tests and technology tests were performed. The hardware and software development process required some standardisation as it was achieved with the Open Wearable Computing Platform and the Open Wearable Computing Framework. Especially for the wearable user interface and the context detection a standard solution was found, could be applied and evaluated in two different working environments with different cultural backgrounds. To have separate tests for the usability and the technology is one of our lessons learned. Voice recognition requires special skills of the end users which must be trained and cannot be assumed as given in a blue collar environment when the working language is not the native one. Furthermore the involvement of really all stakeholders is required to end up with solutions ready for use in the real industrial environment.

REFERENCES

- [1]wearIT@work: Empowering the Mobile Worker by Wearable Computing, WWW page. <http://www.wearitatwork.com>, accessed 25.2.2007.
- [2]Boronowsky, M. Gong Li, Herzog, O. Rügge I. *Wearable Mobile Computing – a Paradigm for Future European eWork*. In: Cunningham, P.; Cunningham, M. (Eds): eAdoption and the Knowledge Economy: Issues, Applications, Case Studies, IOS Press, 2004, 1441- 1447.
- [3]Herzog, O., Knackfuß, P. Lawo, M. Boronowsky, M. *wearIT@work - Empowering the Mobile Worker by Wearable Computing – the First Results*. In: Pallot, M.; Pawar, K.S. (Eds): Proceedings of the 1st AMI@work Communities Forum Day, Munich, June 2005, 38-45.
- [4]Boronowsky, M. Herzog, O. Knackfuß, P. Lawo, M. *Wearable Computing – a New Approach in Concurrent Enterprising*, Proceedings of the ICE 2006, Milan, June 2006, 229-236.
- [5]Stiefmeier, T. Lombriser, C. Roggen, D. Junker, H. Ogris, G. Tröster, G. *Event-Based Activity Tracking in Work Environments*. In *Proceedings of the 3rd IFAWC* (Bremen, March 2006). VDE Verlag, Berlin, 91-100.
- [6]Maurtua, I. Pérez, M.A. Unceta, M. Garmendia, I. *Experimenting Wearable Solutions for Workers' Training in Manufacturing*, accepted for publication at the 12th Int. Conf. on Human-Computer Interaction, to be held in Beijing, July 2007.
- [7]Maurtua, I. Kirisci, P.T. Stiefmeier, T. Sbodio, M.L. Witt, H. A Wearable Computing Prototype for Supporting Training Activities in Automotive Production. In *Proceedings of the 4th IFAWC* (Tel Aviv, March 2007), VDE Verlag, Berlin, 45-56.
- [8]Morales Kluge, E. Witt H. Developing Applications for Wearable Computers: A Process Driven Example. In *Proceedings of the 4th IFAWC* (Tel Aviv March 2007), VDE Verlag, Berlin, 23-34.