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Wearable Computing – a New Approach in Concurrent Enterprising

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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. Thus wearable computing is ideal to develop new insight into the behaviour of the Concurrent Enterprise. Currently wearable computing is still a technology of niches and in a laboratory stage. However, with *wearIT@work* a project dedicated to applications was launched by the European Commission (EC IP 004216). The first 18 months of this project are over and demonstrators, evaluations and results are available. In this paper the concept of the project is briefly introduced and results are presented showing the impact of wearable computing for the Concurrent Enterprise. This impact is based on the cyclic and user centred design approach in developing the different pilot application demonstrators for the four application domains of maintenance, production, healthcare and emergency response.

Keywords

Wearable computing, applications, user centred design

1 Introduction

wearIT@work [*wearIT@work* 2006] was chosen by the European Commission as an Integrated Project to investigate “Wearable Computing” as a technology dealing with computer systems integrated in clothing. The project has 36 partners, among them EADS, HP, Microsoft, SAP, Siemens, 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. For the background of the project and first results see [Boronowsky, Gong, Herzog, Rügge, 2004] and [Boronowsky, Herzog, Knackfuß, Lawo, 2005].

Computer systems integrated with clothes, the so-called wearables, are an approach to develop new insights into the behaviour of the Concurrent Enterprise. These novel computer systems support their users or groups of users in an unobtrusive way in different industrial environments. The basic idea is to allow the users to perform their primary task without distracting their attention enabling computer applications in novel fields. Interaction with wearables by the user is minimal to realize optimal overall system behaviour. For this reason a wearable computer has to recognize the current work situation of a user by integrated sensors. Based on the detected work context the system has to push useful information to its user, e.g., how to proceed with the work by probably reducing possible options to a minimum. Apart from speech output, media could be optical systems presenting the information, e.g., via semi-transparent glasses within the worker’s visual field.

One of the major challenges of this new technology is to investigate the user acceptance of wearables. Suitable methods for user interaction and processes suited to wearables in industry are far from being settled. Investigations show that methods to detect the work context and a general architecture of wearables as well as a hardware and software platform for the implementation of wearables are urgently needed. For four industrial pilot applications, namely emergency response, variant production, maintenance, and healthcare in the *wearIT@work* wearable

computing solutions are used to research how mobile worker can be empowered for the Concurrent Enterprise.

The worldwide market for general-purpose computing/communications wearable systems will by a VDC study [Krebs, Shumka, 2005] exceed \$ 170 million in 2005 and is expected to reach \$ 270 million by 2007 with a growth rate of 24%. VDC estimates the global market biophysical monitoring wearable systems will exceed \$ 190 million in 2005 and is expected to reach \$ 265 million by 2007 (growth rate 17.5%). While there are a small number of products currently on the infotainment market (such as the Oakley "Thump" sunglasses, Bluetooth headsets, etc.), the market remains nascent, and it is unclear what the dominant business model(s) will be in future.

2 Relation to Existing Theories and Work

The focus of *wearIT@work* is on applications and solutions with impact on productivity as achieved by the VuMan [Smailagic, Siewiorek, Martin, Stivoric, 2001] or with economic importance like the WSS 1000 [Stein et al 1998]. A mayor draw back in past developments in wearable computing was just the fact that these developments lacked user acceptance. Therefore the project follows the successfully in wearable computing applied user centred design approach based on rapid prototyping [Siewiorek, Smailagic, Salber, 2001].

There are different approaches to defining wearable computing depending on the research direction and the application domain. When focussing on the interaction between the user, the system and the environment the difference between mobile and wearable computing becomes obvious. In conventional mobile systems the interaction is based on a modified version of a desktop human computer interface (HCI). To operate the system, the user needs to focus on the interface. In contrast, wearable systems are designed to be permanently useful and usable in a wide range of mobile settings. The corresponding interaction concept allows the user to simultaneously interact with the system and the environment.

More advanced wearable systems can detect complex activities such as social interaction, or certain specific work related actions (e.g., in maintenance) and use this information to deliver a variety of services exactly tailored to the user needs in a given situation. Because of the limited space we refer to [Herzog et al., 2005] for further details.

3 Research Approach

Our research is divided into three innovation cycles with a duration of 18 months each based on the user-centred design (UCD) approach [Vredenburg, Isensee, Righi, 2002]. The developments are triggered by four UCD teams for the four pilots. It is assured that all partners of the project contribute at least to one UCD team. Furthermore a technical deployment team assures that synergies emerge between the pilots, a common hardware platform and software framework.

Starting with scenario definitions in scenario writing workshops and discussions between the stakeholders in at least triple design requalifications by workplace studies the requirements and the context of use were specified. Design workshops with the end users decided on aspects and parts of the final solution. They started with a low-fi environment simulation based on paper models, which allowed end users a maximal participation. In a more hi-fi environment simulation interactive VR tools were used giving end-users also some fun. The results from the low-fi simulation were already used here and results from hi-fi simulation validated and enriched the low-fi simulation. In the real environment by physical mock-ups in the lab or on test sites, finally the results from the simulation could be used and this hi-fi simulation could vice versa be used beside validating and enriching also to replay and analyse observations in the real environment. This resulted in a "Living Lab" or Concurrent Enterprise with maximum validity (see [Klann, Shahid, 2005] for further details).

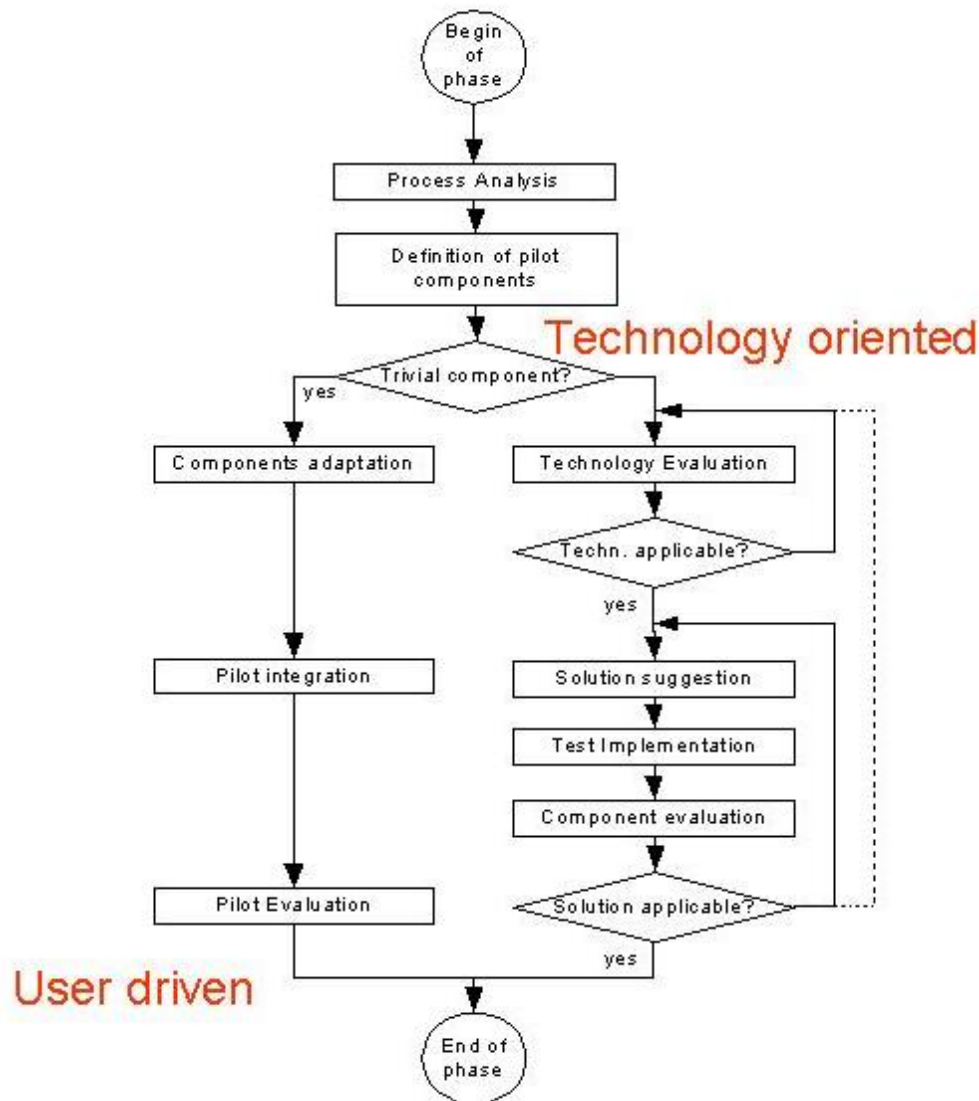


Figure 1: Development methodology

Within the now finished first innovation cycle of the project it became obvious that we have to follow two tracks in our development (see fig. 2). One track (user driven) is based on mock-up prototypes with at most commercial off the shelf (COTS) components. Here empirical studies are carried out, e.g., using the Wizard of OZ approach for speech input. But there are also open questions concerning the technology, e.g., ad hoc communication in hostile environments like smoke and fire or the integration of a head-mounted display into a fire fighter's helmet. For this purpose another track (technology driven) is dedicated to these open questions that require an experimental study using some sort of real, implemented system. Systems or system components best suited to perform the corresponding experiments are determined, implemented, and evaluated. At the end of each phase any applicable solution for a system or a system component becomes a candidate for a commercial product and is taken in the subsequent innovation cycle for pilot integration and evaluation. All solutions are evaluated in each cycle concerning their social and economic impact and their impact on working conditions and new working opportunities [PASHER et al, 2006].

4 Findings

Based on the above described research approach in the first innovation cycle of the wearIT@work project six demonstrators, one for the healthcare (fig. 3), one for the maintenance pilot, and two each for the production and emergency response pilots were developed and evaluated.

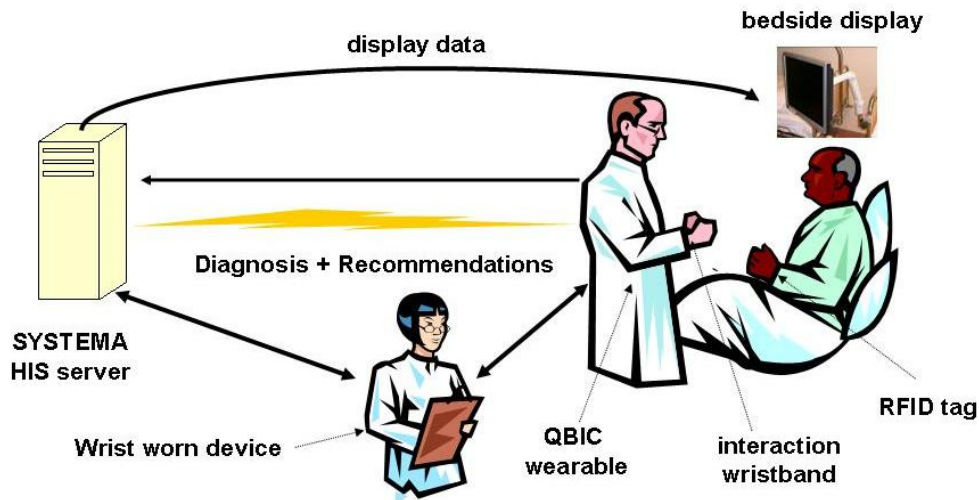


Figure 2: Healthcare demonstrator

As an example illustrating how all stakeholders including the citizen as a patient participated in the design and experimentation of this new approach using new methods but only very little new technology. The healthcare demonstrator and its development is described in more detail here.

The development of the demonstrator for an improved ward round in a hospital is based on three workplace studies. In the first study the work processes were observed to identify those activities to be supported. Social and environmental constraints were identified. Interviews with doctors and nurses were used to find the opinions on possible concepts and their integration into the daily work. For the second workplace study out of the results of the first one a mock-up application using macromedia Flash running on a tablet PC for the doctors and a PDA for the nurses was used in the context of a participatory design workshop. The doctors and nurses got the chance to try out the mock-ups, commenting on advantages and disadvantages, suggesting changes and improvements for the first functional prototype. Out of this the first requirements were derived and used for the construction of a functional prototype/demonstrator.

The demonstrator is based on COTS (Commercial Off The Shelf) components except the interaction wristband of the physician and the HCI the nurse uses on her PDA. All other devices are part of the existing hardware and software infrastructure at the Gespag hospital in Steyr/Austria. There is a bedside screen usually used for the entertainment of the patient, which allows the physician via WLAN to have access to the hospital information system (HIS). The patient wears a wristband with a RFID tag. The physician wears the QBIC belt-computer [QBIC, 2005] with WLAN access, a headset for speech input, a wristband with a RFID reader, and a wristband with a motion sensor. In this way the physician's hand can be kept sterile during the operation of the systems. The nurse wears a RFID tag and has a PDA with WLAN access to the HIS.

The operating process is as follows [Carlson et al., 2006]: When the physician approaches the patient's bed the bedside computer gives access to the HIS. By approaching the patient's wrist the patient's HIS data are displayed on the bedside display. The physician can interact with the HIS by gestures monitored by the wristband and interpreted similarly to mouse input. By speech input the physician can place orders for the nurse that can be processed at the patient's bedside

while the physician authorises the nurse's input by simply being in the vicinity of the nurse. Ten teams of a physician and a nurse determine the user acceptance of the presented HCI. A mayor finding was that mental stress was reduced although some participants expressed opposition to being constantly monitored. Furthermore older staff members reported that they are concerned about having such advanced computers describing themselves as computer illiterate. Details are given in [Carlson et al., 2006].

At Airbus and EADS Sogerma facilities the operator's job and maintenance competitiveness should be enhanced by the mobility of workers, the availability of task-dependent information, the localization and detection of areas to be maintained, sharing knowledge, getting remote expertise, direct reporting, and continuous operator training.

The focus was therefore on information intensive tasks requiring intensive training where three scenarios were chosen: Removal and installation, Trouble shooting, and Inspection.

The approach was very similar to the above described in healthcare, although much more effort had to be made to better understand the underlying workflows, which meant using new technology to also change work processes. It was also necessary to answer some technological questions occurring, e.g., concerning the communication in the aircraft maintenance environment. Therefore two kinds of functional prototypes were required, one reflecting the user-driven requirements and another one to answer technological questions.

Based on the requirements defined by end-users at the project partner EADS, advanced XML-based content management functionalities are covered with an automatic tracking of user actions, a wearable multi-device delivery and rendering of information integrated with a speech-based interaction engine, innovative concepts and metaphors for information presentation and navigation, a multimodal graphical user interface, an automatic management of the reporting phase with task closing, intra- and extra-team communication, and a remote expertise feature. Tests with selected end users were performed and field tests are carried out to further evaluate the application of the approach [Bo, Lorenzon, 2006].

The content management system is based on eXact iTutor from Giunti [Leranexact, 2005]. The information presentation, the reporting, the voice-based interaction, and the Multitel speech engine, as well as different wearable computing hardware components were integrated and tested by selected end users. On the technology-driven track tests concerning the network infrastructure, the remote communication, expertise, and access to information were performed [Hoffmann et al, 2006].

In automobile assembly, although the fabrication of body and chassis are typically automated, the final assembly of interiors, trim, and lighting are manual. Workers receive training at the Skoda factory in Vraclabi in the so called Learning factory. There they receive theoretical training in the e-Learning Institute and practical training at the Learning Island. The goal is to support the training at the Learning Island by further integrating the theoretical training into the practical training. As the performed tasks and their evaluation strongly rely on the context, two demonstrators supporting the final assembly of the front light of a Skoda Octavia (see fig. 5) were developed. Approximately 5 to 6 hours training of the worker is today required for this task by an experienced trainer. User acceptance of wearable computing solutions was evaluated with one demonstrator. The second demonstrator was to identify appropriate sensory systems for automated task sequence and context detection during manual assembly tasks. The result was evaluated during the assembly of the front light mentioned above [Stiefmeier et al, 2006].

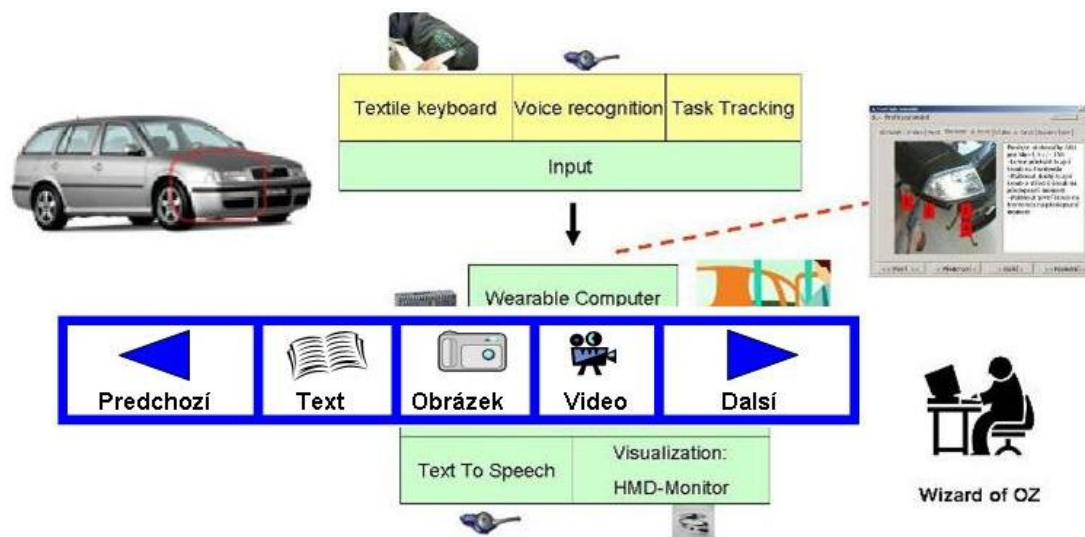


Figure 3: User-oriented production demonstrator

Because of the limited space only the user-oriented demonstrator is explained here: The worker is equipped with a belt computer similar to the physician in the healthcare scenario, a HMD, and a Bluetooth headset for speech in-/output receiving information from an operator of the Wizard of OZ simulator. The application prototype was developed to display information on the HMD; speech in-/output is managed by the operator using the wizard of OZ methodology. The worker can navigate through the application by simulated buttons on his overall; different locations of the buttons were evaluated. The tasks a worker performs are tracked implicitly without conscious interaction; in case the worker forgets anything, e.g., a screw or a measurement, the system detects it and informs the worker; the worker can demand multimedia supervisory support provided by the operator. The results of this second demonstrator are used to further integrate sensory systems into the wearable computing solution of the first one.

As we face a pilot scenario in emergency response and obviously with the Paris fire brigade (BSPP) as the end user organisation with a very high degree of complexity a lot of effort was made to involve the end users and to better understand the processes and requirements; the user-oriented track of development took most of the effort: To understand the context of use seven workplace studies with a duration of up to three weeks (intervention command training) were performed. Requirements were based on a scenario writing workshop refined by the workplace studies and three design workshops. The design workshops used paper based simulation, interactive prototypes, physical mock-ups, and virtual reality simulation.

The technology track covered tests for the wireless communication under fire and smoke conditions and HMD helmet configurations [Bretschneider, Brattke, Rein 2006]. In the next section an example of a ready-to-use solution developed in close cooperation of the Emergency Response UCD team led by Fraunhofer FIT and an end user is given.

5 Conclusion

In healthcare and maintenance, first tests of the demonstrators with selected end users were performed showing that this approach of a Concurrent Enterprise or Living Lab is promising enough to be followed for the next three years of the project with minor modifications. Tests with extended user groups are part of it. The results of these investigations influence the design process in the recently started second innovation cycle of the wearIT@work project.

In production and emergency rescue the need of native speakers to communicate with the end users requires a lot of effort, as only English and Spanish but no Czech speech recognition modules are actually available for the production pilot.

As one result of the close cooperation between end-users and developers a very simple solution was achieved (see fig.6) for a challenge of the emergency response scenario. At BSPP a graphic artist with more than 25 years of experience as fire fighter takes a sketch of the scene in case of a complex mission, e.g., from top of a turntable ladder or other positions. This sketch is sent by fax to the command post supporting the rescue management. Tests with tablet PCs to optimise this work flow failed, but using the Anoto digitizing technology and a mobile phone the developers found a very easy way to meet the end user's requests. In a 90 minutes design cycle and a development cycle of seven days an solution accepted by the end-user was implemented.

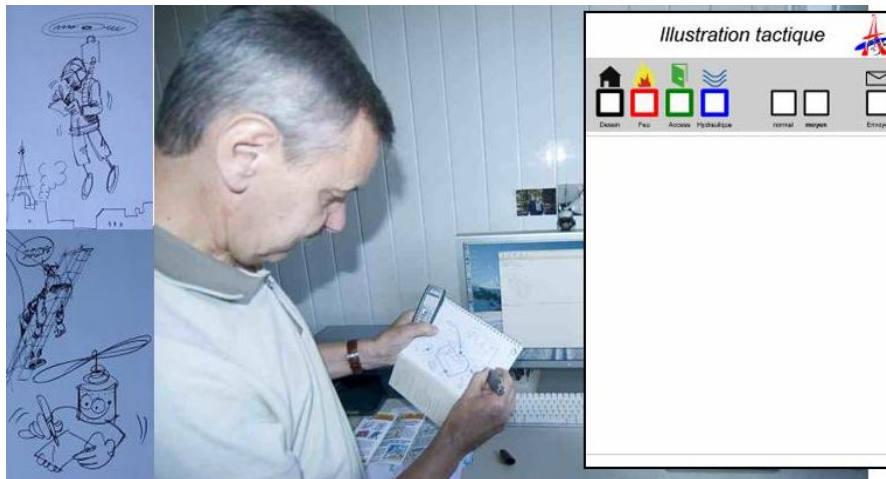


Figure 4: User-driven emergency response demonstrator

One of the issues of our work is the business benefit achievable by wearable computing. Hard figures depend on the application domain and the scenario. Today, however, in the healthcare scenario, during a ward round teams of two to six persons are involved. Ward rounds take, e.g., 20 minutes for 15 patients and require extensive back-office rework of the nurse and the physician of more than an hour in total. Based on the healthcare demonstrator the time at the patient's bed is extended and the office rework which is disliked by the end users is reduced drastically. Further investigations are necessary to confirm the expected increase of productivity by 50% leading to the double time at the patient's bed. Furthermore an increase in quality is achieved as, e.g., medications are directly recorded and no longer transcribed during rework in the back-office; media clashes with time consuming and error-prone conversions are avoided.

A similar situation is envisaged in the maintenance field: extensive workplace studies proved that workers spend up to 50 % of their working time by just walking between the shop floor and the place of operation at the plane. Only by providing the information in an appropriate wearable computing format directly to the maintenance worker the productivity increases significantly. However, appropriate HCI and context detection solutions are still under development, and depending on the success of these developments real benefits have to be evaluated in extensive ethnographic studies based on these and further demonstrators.

In this paper the results of the first 18 months of the comprehensive EU IP wearIT@work on wearable computing were presented. There are still three years of work to be done, and there is still some way to go, but the fundamental steps towards pilot demonstrators based on a user-centred design approach, a hardware framework and software platform are done. With the creation of the Open Wearable Computing Group [Knackfuß, Lawo, Boronowsky, Herzog, 2005] and by organising the annual International Forum on Applied Wearable Computing [IFAWC, 2006], a community building process in industry and science has been initiated. It is the intention of the project and the accompanying activities to understand the project as the seed for an increasing wearable computing business. Appropriate wearable HCIs, ambient wearable computing context detection solutions, the miniaturisation of components, and the power

management are still a challenge as well as a reliable ubiquitous wireless communication. However, the consortium is convinced to be on the right way in following an appropriate approach of Concurrent Enterprising or even the Living Lab idea.

Acknowledgement

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