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ON THE USE OF WEARABLE COMPUTING IN AIRCRAFT MAINTENANCE – FIRST RESULTS FROM WEARIT@WORK

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ABSTRACT

Currently wearable computing is still a technology of niches and in a laboratory stage. With *wearIT@work* a project dedicated to applications was launched by the European Commission. The first 18 months of the project are over and the first demonstrators and results were achieved. As the project strongly follows a cyclic and user centred design approach much effort was put on investigations with end users in the four application domains of aircraft maintenance, production, healthcare and emergency response. Demonstrators of wearable computing solutions were achieved and evaluations with end users performed. In this paper the research concept of the project is introduced and results from the wearable computing aircraft maintenance show case are presented.

INTRODUCTION

The *wearIT@work* 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 € by the European Commission under contract no. 004216, it is the largest project world-wide in wearable computing. *wearIT@work* contributes to the shaping of today's most challenging computer applications. The TZI – Mobile Research Center of the Universität Bremen co-ordinates the project.

The focus of *wearIT@work* is on applications and solutions with impact on productivity as achieved e.g. by the VuMan [1] or economic importance like the WSS 1000 [2]. The project follows the user centered design approach as successfully applied in wearable computing previously [3]. The first technological results of the *wearIT@work* project were already reported previously [4].

OBJECTIVES

Although during the last 20 years a lot of research was done in wearable computing the human computer interaction and the context detection require still further research. By a common hardware platform and software framework for wearable computing [4] the project contributes to standardization. The large partners in the software business mentioned above assure the necessary impact for the exploitation of the project results whereas the SMEs in the consortium are systems integrators and consultants and base their application development on the hardware platform and software framework; they prove in such a way the validity of the unique project approach and the ability to create business in the fast growing market requiring wearable computing devices not only in Europe.

The worldwide market for general-purpose computing/ communications wearable systems will by a VDC study [5] 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.

The intention of wearIT@work is to prove the applicability of computer systems integrated into clothes, the so-called wearables, in various industrial environments. These novel computer systems support their users or groups of users in an unobtrusive way wearing them e.g., as a computer-belt. The aim of wearable computing is to allow users to perform their primary task without distracting their attention enabling computer applications in novel fields. Interaction with wearable devices by the user must be minimal to realize optimal system behaviour. This can only be achieved by integrated sensors recognizing the current environment and the work progress of a user.

METHODOLOGY

Our research is based on a cyclic innovation approach and the user centred design (UCD) approach as defined in ISO 13407. There are three innovation cycles with the duration of 18 months each. Based on scenario definitions and discussions between the stakeholders of the project and the application partners workplace studies are continuously performed at the site of the users to validate the scenarios.

Based on the work context detected the system has to push useful information to its user, e.g., how to proceed with the work. Using scenario definitions and discussions between the stakeholders of the project and the application partners workplace studies are continuously performed at the site of the users to validate the scenarios. By this analysis it became obvious that we have to follow two tracks of development (see Fig. 1). 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 in and around an aircraft under maintenance conditions. 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.

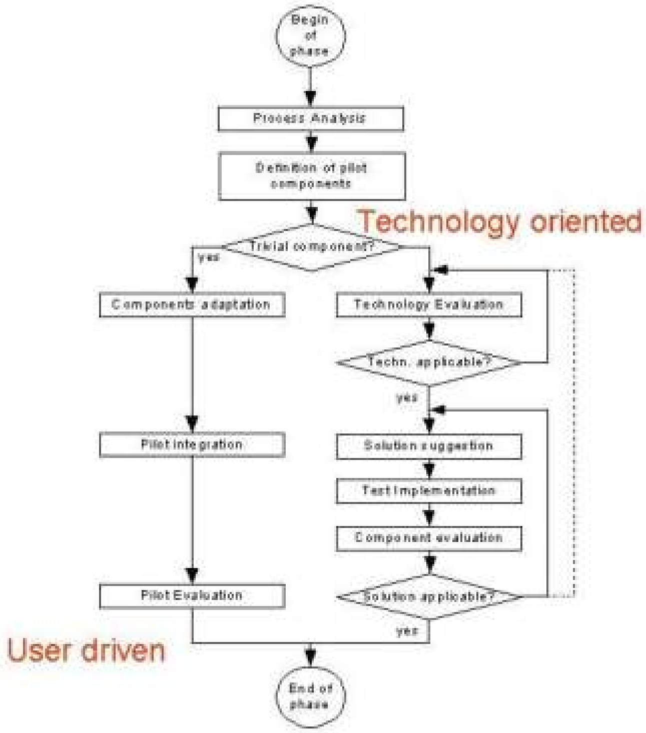

Fig. 1 Development methodology

DEVELOPMENTS

The development is based on the overall system architecture described in [4]. At this stage of the project no software framework was used although first components were identified and developed [8], [9]. Six demonstrators were developed. The technology development focused on context detection based on different sensory devices and wearable computing specific human computer interfaces (HCI). To focus on the applications we omit the detailed description of the technology here.

In aircraft maintenance we focus on three scenarios:

- Removal and installation,
- Trouble shooting, and
- Inspection.

Much effort had to be made to better understand the underlying workflows, which meant using new technology to also change work processes (see Fig. 2). 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.

Work teams in aircraft maintenance are geographically dispersed due to the organization of productive plants. In order to improve productivity these teams are expected to pool their knowledge solving problems as fast and efficient as possible.

Under the joint supervision of EADS-CCR (*European Aeronautic Defence and Space Company – Corporate Research Centre*) and GIUNTI Interactive Labs we looked for new ways of improving operators' tasks in order to complement the activity of experts.

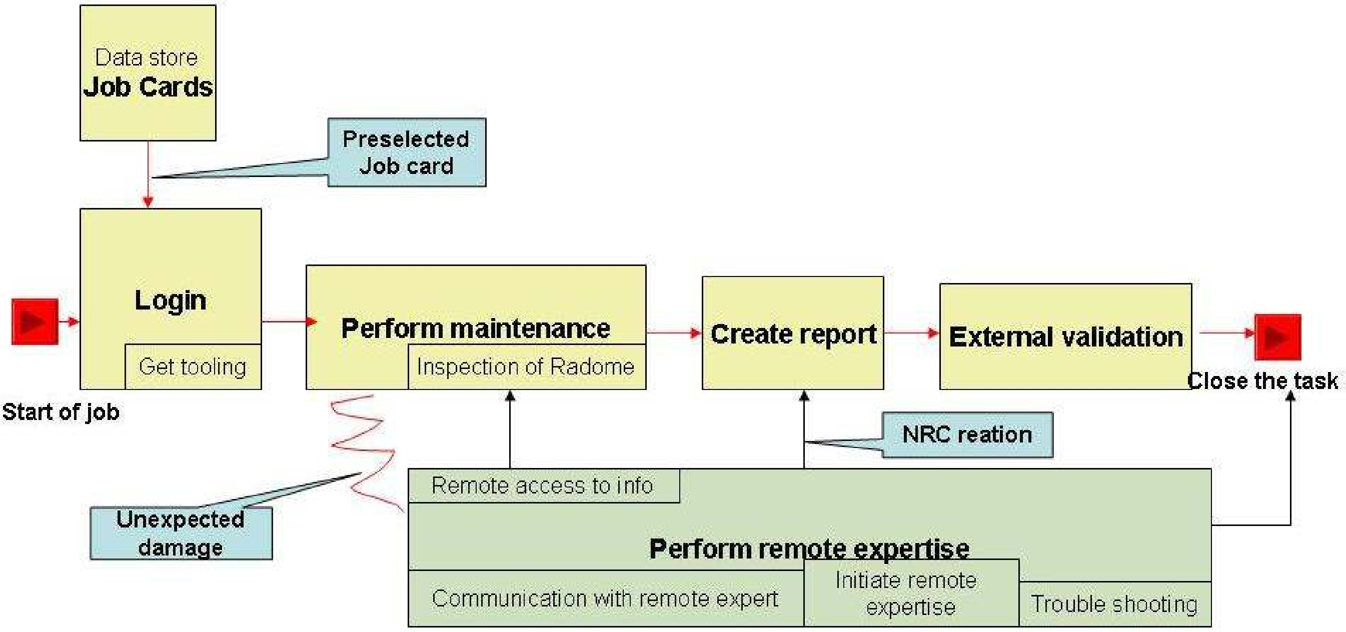

Fig. 2 Inspection workflow in aircraft maintenance

As a matter of fact maintenance aspects are taken into account from the very beginning of an aircraft design. Based on case studies at Airbus and EADS Sogerma facilities in Bordeaux, wearable technologies were researched for improving the maintenance competitiveness. In detail the following aspects were taken into account:

- Increasing mobility of workers
- Improving availability of task-dependent information
- Speed up localization and detection of areas to be repaired or maintained
- Improving communication and knowledge sharing
- Enabling direct reporting
- Supporting continuous maintenance operators training

The performed workplace studies (see [6] for further details) showed that constrained spaces, uncomfortable positions, motion limitations, impacts, water, heat, corrosive products, pyrotechnic, shadow zones, light, noise, security, and confidentiality form a set of requirements to be met by any wearable computing solution to be applied in this work environment.

Based on these requirements a demonstrator was developed covering advanced XML-based content management functionalities with an automatic tracking of user actions, a multi-device wearable 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 will be subsequently carried out.

The content management system (CMS) is based on eXact iTutor from Giunti (http://www.learnexact.com/exact_itutor/ and Fig. 3). 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 [6]. These tests were used to improve the requirements by increasing the level of detail.

FINDINGS

On the user driven track of our research it was possible to remotely access task relevant information stored in a repository. A basics subset of content management functionalities was implemented and is up to now properly working. End-users gave a positive feed-back concerning the way of information presentation improved after the second workplace study. The reporting functionality is available and properly working. However, further tests with users are needed. The voice-based interaction is well working with IBM via voice; users gave positive feed-back. The integration between the content management system and Multitel's speech engine needs improvement.

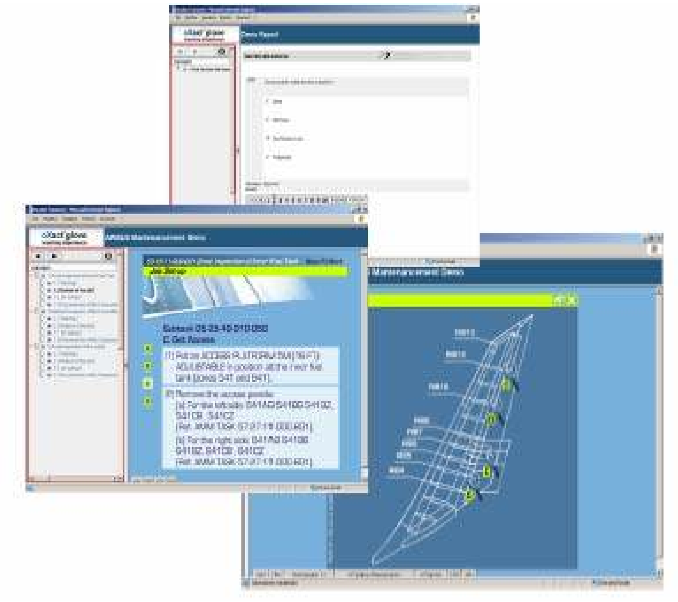

Fig.3 Maintenance CMS demonstrator

The following hardware devices worked well during the end-user tests in the aircraft maintenance environment:

- Xybernaut MA-V + MicroOptical SV-6
- Xybernaut ATIGO-T tablet PC
- HP Ipaq PDA 5400
- Zeiss LA HMD binocular.

On the technology oriented track tests concerning the network infrastructure, the remote communication, access to information and expert knowledge were performed.

For remote communication setting up a reliable wireless connection with Bluetooth headsets for configuring MS-NetMeeting in the real environment turned out to be difficult needing proper preparation. Testing the remote expertise feature requires therefore further investigations (see [6] for details).

For the network infrastructure on an A 330-200 test of different 802.11 (a, b, g/n) technologies were done (see Fig 4). The results were better than expected, as with systems operating in 2.4 GHz frequency band, communication was even possible inside the cabin without additional relay stations at the door. Among the tested technologies, IEEE 802.11g/n has shown the best performance, with more than 7 Mbit/s throughputs in infrastructure mode – nearly independent of the position of the receiver. This data rate is sufficient for high definition video communication. Hence, at this stage IEEE 802.11g/n will be used for communication of the mobile workers (see [7] for details).

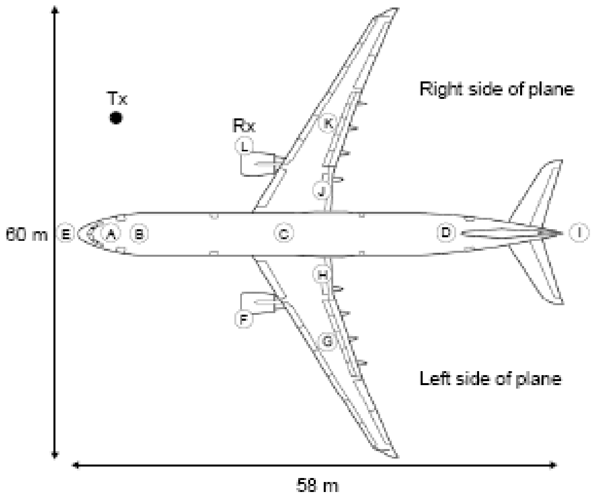

Fig. 4 Position of transmitter (T) and receiver (R)

OUTLOOK

In the future wearable computing will play a major role in the working environment not only in aircraft maintenance. However, the perception of wearable computing requires the vision of an open wearable computing framework and an open wearable computing platform (OWCP) as given in fig. 5 as not just solutions but a new working paradigm is necessary. Transforming the desktop paradigm to a new hardware will not be sufficient.

Based on a wireless body area network (BAN) the project foresees a four-layer-architecture.

Textiles and functional textiles of layer one with reliable textile electronics interfaces interact with embedded microsystems on layer two. The functional textiles will serve as electrodes, data and power lines. They will be an essential part of the interface to the electronics. Functional textiles will also serve for power generation (e.g. solar cells) and sensing (e.g. physiological monitoring).

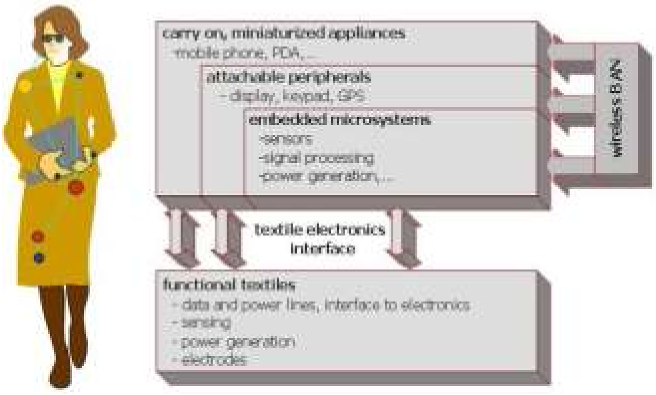

Fig.5 OWCP system architecture

This is a not yet a well established product domain as it is neither pure microelectronics nor textile. Here micro- and nanotechnologies will be of great influence to the technological development in the future. A lot of research in both fields from the wearable computing perspective is e.g. done at the Wearable Computing Lab of the project partner ETH Zurich [10] and at TZI. Examples of attachable peripherals are the QBIC [10] or the WINSPECT and SCIPIO [11]. Here miniaturization is a main issue, as the minimal power consumption of the devices, a sufficient power supply, and an optimal power management are key success factors for the user acceptance of wearable computing solutions.

On the third layer we have attachable peripherals and on the fourth carry on, miniaturized appliances similar to those from mobile computing.

Reflecting the changed working paradigm of wearable computing the interaction with the environment requires a lot of sensors allowing proper context detection. The user of the wearable computing solution should be provided automatically and without direct interaction with the sensor signals. Information in aircraft maintenance could e.g. come from sensors applied to parts monitoring the lifecycle of the part not just only active or passive RFID tags applied to the parts. Thus miniaturized sensors in the environment are essential for a successful implementation and a break through of the wearable computing technology. As in car navigation the sufficient provision with GPS signals is essential and enhances the route planner to a real navigation system, sensors in the working environment are similarly essential for the successful implementation of a wearable computing solution. Here again micro- and nanotechnologies are key success factors.

CONCLUSION

In this paper the results of the first 18 months of the very large IP wearIT@work on wearable computing in aircraft maintenance were presented. There are still three years of research to be done and it is still some way to go but the fundamental steps towards pilot demonstrators based on a user centered design approach, a hardware framework and software platform are done.

In the forthcoming second innovation cycle of the project the maintenance operators will be equipped with a *Maintenance Jacket*, with integrated wearable technologies for training and their daily activities.

From the technology oriented tests in the production scenario we know that task recognition is possible and based on it maintenance procedures with user interaction can be controlled. Using the proposed Maintenance Jacket, the related input/output devices and an advanced content management and presentation system we expect the following advantages:

- Improving the capabilities of workers by also reducing the learning curve slope
- Better management of the company know-how and information pool
- Extend the ability of the workers to handle and relate various situations
- Time reduction for execution of the maintenance procedures
- Improvement of the quality levels, reduction of errors and increase of security of aircrafts
- Maintenance cost reduction and increase of competitiveness.

It is the intention of the project and the accompanying activities to understand the project not as a tree bringing us the fruits but a seed for an increasing wearable computing business. First wearable HCIs, ambient wearable computing context detection and reliable ubiquitous wireless communication solutions are already available and a source for improvements in the next innovation cycle of the project, as well as the miniaturization of components, and the power management.

With the creation of the Open Wearable Computing Group (www.owcg.org) and organizing annually the International Forum on Applied wearable Computing (www.ifawc.org), a community building process in industry and science has been initiated.

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