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## Empowering the Mobile Worker by Wearable Computing

Workshop Proceedings


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# Empowering the Mobile Worker by Wearable Computing
# Wearable Computing Workshop Proceedings

## ICE Conference 2008 Lisbon/Portugal, June 25th, 2008

## Editors:

**Michael Lawo, Michael Boronowsky, Otthein Herzog, Peter Knackfuß**

## TZI Report

# Editorial

Imagine your work completely different. Imagine you have an intelligent assistant able to find any information you need, whenever and wherever. Imagine your personal assistant is always with you, without disturbing you. Imagine you can use this assistant when you want and you can forget him when you don't need. We are creating for you what you are dreaming of!

The wearIT@work project developed a set of new solutions to support the workers of the future.

The wearIT@work project is the largest worldwide in wearable computing research. Focused on work context, this EC Integrated Project displays results ready for exploitation. The European Commission set up wearIT@work as an Integrated Project to investigate "Wearable Computing" as a technology dealing with computer systems integrated in clothing. The project has 42 partners, a project volume of 23.7 million € and an EU funding of 14.6 million €. The project started in June 2004. After 4 years of research the project is ready for exploitation. The last year of the project is just dedicated to this.

Wearable computing technology has the long-term potential to change the out-of-office workplace just as much as personal computers changed the office environment: Instead of working at the computer, users are supported in their primary tasks by the help of ICT. A wearable computer provides persistent, unobtrusive support through IT solutions during all daily work primary tasks. At stakes: improving safety, productivity and comfort at work. WearIT@work project develops a set of such solutions.

Wearable computing introduces new possibilities to use context information from the surrounding environment. This allows for usage of new technology for identification, authentication and authorization at the same time as ambient security threats need to be managed. To foster this approach a series of workshops is planned where the one at ICE conference 2008 in Lisbon/Portugal is the first one www.ice-conference.org. Further workshops will be e.g. at CKIR in Helsinki/Finland, at the eSmart event in Sophia Antipolis/France, at the World Computer Congress in Milan/Italy, at ISWC and IFAWC in Pittsburgh/USA, at ICT 2008 in Lyon/France, and at the ICKMIC2009 (International Conference on Knowledge Management and Intellectual Capital) at IMT Ghaziabad/ India.

The workshops are an opportunity to meet, exchange and learn from the experts in the domain, they are specifically designed to foster exchanges focusing on:

- wearable computing and devices,
- ambient intelligence,
- context recognition,
- security technology,
- social and legal aspects.

Research and industry innovators attending the wearIT@work workshop shall learn the latest findings in context recognition, security and legal challenges for wearable computing, discuss security issues, understand through positions statements why wearable computing marks a technology breakthrough in four application domains: healthcare, emergency response, aircraft maintenance and production management.

For details see wearIT@work website: www.wearitatwork.com

Michael Lawo, Technical Manager wearIT@work

# The Next Six Big Things in Mobility

Thad Starner

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By focusing on iconic services and unique interaction techniques, Apple's iPhone and RIM's Blackberry have become some of the most popular mobile phones, demonstrating the market for sophisticated mobile devices.

What other opportunities are there for the near future?

Extrapolating from academic research in wearable computers from the past 15 years, we present six trends and technologies that should lead to significant commercial activity in the next few years.

From the user's standpoint, the mobile phone will become the most used computing interface, especially in the developing world where the phone is often the only available computing interface. A powerful related trend is the convergence of digital devices on the body, emulating the digital convergence that occurred on the PC in the last decade. Increasingly, services will assume the primary interaction is through the mobile phone, and devices will be created that act as peripherals to the phone. For example, Bluetooth earphones, wristwatch displays, external keyboards, and wireless backup devices will become common. Freed of the hardware constraints required for a user interface, the phone itself may shrink to a small box, carried in the pocket, which contains 1TB of flash memory, an exterior network connection, and a "bodynet" for communicating with peripherals.

As users begin to write lengthy documents on their phones, good text entry techniques will become a powerful differentiator in products. Creative approaches will battle the problem of limited space for keyboards on these devices and the corresponding "fat finger" effect that limits typing speed and accuracy.

New approaches to speech interfaces will appear. Speech will be used as data, allowing it to be searched, attached to e-mails, embedded in documents, and added to commentary on mobile-focused web sites. Users will be able to store ALL of their conversations and voicemail on their phones, and these archives will be searchable using powerful new interfaces. Voicemail-like interfaces will be offered in developing areas to allow asynchronous and inexpensive communication.

Similarly, gesture will appear as a interaction technique for mobile devices. A shake of the wrist will send an incoming call to voicemail. Tilting the phone will allow users to scroll through menus - especially useful when the phone is too small to have a keyboard or when the user's hands are too arthritic for fine button presses.

Finally, augmented reality, long an academic curiosity, will begin to find purchase on the next generation of powerful mobile phone processors. Applications may include way finding, conferencing, tourism, shopping, and mobile social games.

# Results Overview on the Activity Recognition Problem in the Škoda Production Scenario

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**Abstract**

The work described is part of the wearIT@work project, financed by the European Union project; it aims at evaluating the use of wearable technology in production environments and at facilitating complex task tracking in real-life industrial environments. To this end the paper looks at a complex, realistic case study closely modelled after a real industrial application. We focus on how highly multi-modal sensor systems can be used in a flexible, modular way. Thus methods allow addition and removal of sensors with little changes to the rest of the recognition systems. Similarly new activities can be added without impact on the recognition system regarding the old activities. Finally the sensors and algorithms used for spotting can be selected and fine-tuned separately for each activity.

## 1 Introduction

Monitoring and recognizing human activity has emerged as one of the key research topics in pervasive and ubiquitous computing. It enables applications such as assisted living, industrial work-flow optimization and novel HCI interaction paradigms.

This paper focuses on a specific type of activity recognition: the spotting of sporadic actions using wearable sensors. Examples of sporadic actions are opening a door, picking up a phone, or fastening a screw. Spotting aims to locate a set of relevant actions in a continuous data stream in which they are randomly mixed with a large body of arbitrary non-relevant actions.

The main difficulties are ambiguities in the sensor signal, high percentage of NULL class events, lack of appropriate models for the NULL class, and high variability in the duration of relevant events.

The work described builds on a wide body of previous research by the authors. It is part of a large industrial project on the use of wearable technology in production environments ([1]) and aims at facilitating complex task tracking in real-life industrial environments. To this end the paper looks at a complex, realistic case study closely modelled after a real industrial application. We focus on how highly multi-modal sensor systems can be used in a flexible, modular way. Thus methods allow addition and removal of sensors with little changes to the rest of the recognition systems. Similarly new activities can be added without impact on the recognition system regarding the old activities. Finally the sensors and algorithms used for spotting can be selected and fine-tuned separately for each activity.

A typical activity spotting problem is defined by a moderate set (in the range of 10 to 100) of user actions which the systems needs to identify in a continuous stream of data. As an example in the specific case study described in this paper the task is to track the progress of a quality inspection procedure at the end of the car production line. There was neither a specific sequence nor a time frame within which the activities were to be executed. In between the relevant actions the workers could perform arbitrary other activities. The sensor system used in this case study consisted of 7 motion sensors (each is a combination of a 3 axis accelerometer, a 3 axis gyroscope and a 3 axis digital compass) monitoring the motions of different upper-body parts, 16 FSRs to monitor arm muscle activity and a high accuracy indoor location system to determine the position of the user with respect to the car.

The major challenges in the spotting task can be summarized as follows:

**Ambiguity of individual sensor signals.** In general most activities can not be unambiguously characterized with a single on-body sensing modality. Even within a single application different activities are likely to have different sensing modalities that best characterize them. The same is true for feature sets. As a consequence, spotting systems need to be highly multi-modal. They also need to use different sensing modalities and features in an adaptive way.

**NULL class size.** In many applications the relevant actions comprise only a small amount of the overall measurement time. In the car production example given above only about 30% of the total time was related to relevant activities. In other scenarios such as monitoring household activities this time can be as low as 1%. This means that the system needs to be highly selective to avoid a prohibitive number of insertion errors.

**Lack of NULL class models.** In activity spotting the NULL class can be vaguely described as ’all possible human actions other than the ones belonging to the set we need to spot’. Clearly, given the complexity of human actions, no useful model can be derived. Thus the spotting system needs to work with absolute thresholds for the similarity to the individual relevant classes rather than with relative similarity between relevant classes and the NULL class.

**High variability in event length.** Human actions can significantly vary in length. This is true both within a certain activity class and between different classes. The difference that the system has to deal with can be in the range of several hundreds percent. As a consequence obvious techniques such as fixed sized sliding windows and correlations are often not applicable.

## 2 Experiments

We collected data in-situ at the Škoda production facility. A worker wearing the Motion Jacket performed the procedure on ten cars, while the cars were moving on the conveyor belt of the assembly line. With these recordings we proved the reliability and robustness of our sensor system under real life conditions. In addition, we observed and filmed several other workers performing the procedure for later analysis.

Due to the high cost of interruptions, large scale data recording within the production process is not possible. The only way to collect a comprehensive data set is to recreate the production environment in our lab. For that Škoda provided us with a complete car. The video material from the factory was used to ensure a realistic setup.

On this recreated setup we recorded a dataset with 8 subjects (students, instructed from the video material) who each conducted 10 repetitions of the procedure (Table 1). One experimenter annotated the start and end points of activities to provide an absolute reference (ground truth), while a second experimenter annotated the location ground truth of the user simultaneously. both using the CRN Toolbox [2] to synchronize the annotation streams with the data streams. We collected about 3680 checking activities within 560 minutes of data.

In [1] we describe the Motion Jacket that we developed to integrate the required sensor modalities in an unobtrusive and robust working jacket. We capture the upper-body motion of the worker from seven IMUs (Xsens MTx) within the jacket. The IMUs are placed on the lower arms, the upper arms, the torso, and on the back of the gloves. Two data acquisition units collect the data from these IMUs. The IMUs allow us to capture arm and hand motion, which provides information about the activity performed by the worker. The muscle activity of the lower arms is picked up using two custom built sleeves, each integrating an eight channel FSR unit. The worker's relative position to the car body is measured with an UWB positioning system. Four Tags on the worker's shoulders enable the system to calculate his position with respect to four reference transmitters placed around the car.

| class ID | class name | location classes | gesture type |
|---|---|---|---|
| 1 | open hood | 1 | b |
| 2 | close hood | 1 | b |
| 3 | open trunk | 5 | b |
| 4 | check trunk | 5 | b |
| 5 | close trunk | 5 | b |
| 6 | fuel lid | 6 | r |
| 7 | open left door | 4,8 | l |
| 8 | close left door | 4,8 | l |
| 9 | open right door | 6,7 | r |
| 10 | close right door | 6,7 | r |
| 11 | open two doors | 6,8 | b |
| 12 | close two doors | 7,8 | b |
| 13 | mirror | 3 | r |
| 14 | check trunk gaps | 5 | b |
| 15 | lock check left | 4,8 | l |
| 16 | lock check right | 6,7 | r |
| 17 | check hood gaps | 2,7 | b |
| 18 | open the spare wheel box | 5 | r |
| 19 | close the spare wheel box | 5 | r |
| 20 | writing | 4,7 | b |

Table 1: Activity classes and appropriate location classes.
The last column defineswhich hand is involved (r=right, l=left, b=bi-manual).

## 3 Results

**Door related actions.** The bulks (6 out of 13) of the activities with mediocre and poor spotting results are related to doors. There are two main reasons for this:

1. Opening and closing the door allows a huge degree of variability in a way it can be performed. There is only a short characteristic part: pulling the handle to unlock the door. After that one can continue to pull on the handle, or use one or the other hand placed on an arbitrary part of the frame to finish opening the door. In the case of opening both doors at the same time much of the pull comes from body motion as it is difficult to pull both doors at the same time without moving the body. Such slow body motions are much more difficult to recognize then distinct arm actions and occur more often during random activities.
2. Opening and closing the doors also occurred as part of other checking activities without being annotated as an activity for itself. This is particularly grave for the left door, where the muscle activity classifier fails (recall below 83.4%), effecting the muscle plausibility analysis to fail as well.

**Checking the gaps.** Checking the gaps on the trunk (action 14) is among the best recognized actions. Checking the hood gaps on the other hand belongs to the poorly performing activities. At a first glance this may be surprising as these two activities seem related. However, a close look reveals considerable differences. To check the trunk gaps the user stands in the middle behind the car and moves both hands from the top sideward to the bottom. In the process the user has to bend down. This is a very characteristic sequence of motion that is unlikely to occur in other activities. Checking the hood on the other hand consists of running the fingers along the more or less horizontal line between the hood and the fender. This is a subtle motion combined with a posture that can occur in other unrelated activities.

**Writing.** Writing (action 20) is among the poorly performing classes. This is due to the fact that it is not bound to a certain location, has no large characteristic gestures and little distinguishable muscle activity. The only specific thing is the arm posture (lower arms horizontal), which is just not enough for reliable spotting. More information on finger motion and subtle hand motions would be needed here.

**The fuel lid.** The fuel lid is in the middle group. With an excellent recall (91.4%) but just 54.6% precision it is just out of the ’good’ group. The activity has a characteristic turning motion associated with opening and closing the lid and a reasonably well defined location. On the other hand it is fairly short and subtle; and similar actions can occur in unrelated activities. This accounts for the poor precision. Three main observations result from an analysis of the precision/recall plots of individual activities.

1. While the performance of the individual masking approaches varies greatly from activity to activity, the combination of all approaches consistently remains best or very close to best for all classes. The only exception are the left door classes, on which, however, results are very poor for all approaches.
2. With the exception of activity 8 (close left door) the initial fast spotting sweep nearly perfectly achieves the goal of high sensitivity and has a recall in the nineties.
3. The precision recall plots of the activities can be put into four groups. In the first group the application of the different masking techniques produce steep gain in precision (up to around 0.9) with no or little loss of recall. Activities 1, 4, 5, 13, 14 and 18 belong to this class. In short these result means that our sensor system is perfectly matched to capture the unique characteristics of this activities. In the second group (activities 6, 9, 15, 16) the filtering also retains high recall but the gains in precision level are in average around 0.6. In the third group (activities 3, 10, 19 and 20) we see both the leveling off of the precision gains and a significant drop in the recall. Finally we have the group of activities where the system can be said to fail (7, 8, 11, 12, 17) and the filtering leads to a large drop in recall with no adequate gain in precision. For these activities we can conclude that additional or different sensing modalities are unavoidable.

From the results given and discussed above a number of lessons can be drawn, that, we believe, are significant beyond the specific car inspection example.

**Importance of consistent class definition.** The poor performance of the door related activities underscore the importance and the difficulty of a consistent definition of an activity. As described in the previous section the problem can be traced to the similarity of actions belonging to different door closing classes and an overlap with parts of other actions (which also require opening the door).

**Slight variations in the task setup can be crucial.** Seemingly similar activities performed under slightly different circumstance can be dramatically different in their recognition complexity. This is illustrated by the example of checking the hood and the trunk gaps. From a high level task description both sound similar and aim to achieve the same thing. However, in terms of recognition difficulty they are very different.

**Inadequate sensing for subtle gestures.** The FSRs have been included in the setup as a way to get information about subtle palm and finger motion related to activities such as for example writing. It turns out that this did not work as expected. As discussed in the previous section the FSRs clearly improve the overall performance of the system. However, they do not provide sufficient information to achieve the original goal. There are two conclusions from this observation. One is the need to improve the FSR system. The other is to add further sensing modalities such as sound, proximity sensing, or even wrist mounted cameras.

**Merit of separate recognition chains for each action.** Our system has made extensive use of the possibility to independently tune the parameters for each of the investigated activities. This tuning has significantly improved the results. At the same time we have seen that the final fusion step does not introduce many deletions.

**Merit of the incremental, masking approach.** While it is difficult to find sensing modalities that fully capture the unique characteristics of certain activities, it is often easy to find sensors that contain certain necessary (but not sufficient) conditions for this activities to occur. The FSRs are a prime example of such sensors. While the signals from our system are often not unique to a certain activity, we can say that some activities can not have occurred. The similar can be said about user location with respect to the car. The incremental masking approach is perfectly suited to exploit this. The improvements achieved through the individual masking passes and the variations in the effect of the passes on different activities confirm that. As the main performance issues are insertion errors it can be assumed that further masking passes with new sensing modalities (e.g. sound) should produce considerable improvements.

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# Supporting Mobile Workers in Car Production by Wearable Computing – Applied Context Detection

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**Abstract**

Today's requirements in production process efficiency combined with their increasing complexity represent a great challenge for staff members at all levels (from the assembly worker to the plant manager). The ultimate goal is the fine-tuning of the production process to perfectly fulfil customer orders and to keep the overall efficiency at high levels.

Through scenarios based on real situations, and tested in a real industrial environment (a Škoda car manufacturing production plant), the wearIT@work project demonstrates how wearable technology can allow an efficient, successful working environment by providing ubiquitous, mobile access to production process-related information where and when necessary: at the shop floor, at the assembly line, and at the manufacturing workstations. This allows workers at different levels to improve the training process of inexperienced workers, to improve availability of information, to speed up localisation and detection of areas to be repaired or maintained as well as to improve communication and knowledge sharing.

This paper describes the used context detection techniques, which are used to support mobile workers in car production by wearable technologies.

**Keywords**

Context detection, wearable computing, production, user centred design

## 4 Introduction

Actually industrial companies act in a very difficult business environment, which can be characterized by an increasing dynamic of innovation and a reduction of the product lifetimes. In the same amount the products and the production processes become more and more complex. This results in high demands on the production processes and on the involved employees.

In this context the omnipresent availability of product related information is one of the major key success factors. This should be available every time, everywhere and for each employee. Today the majority of the process and product related data is stored in different IT systems and databases: technical information (CAD models, work plans, NC control information, etc.) are stored in PLM systems, job specific information in ERP systems; beneath this self made solutions are used in dedicated departments. Insofar the required information is basically available within the company, but the access to it is generally difficult, time intensive and limited to dedicated stationary PCs. Thus the achievement of the required information has become a very time and cost intensive process.

Nowadays the simulation of production sequences is a common tool in order to safeguard strategic and tactical decisions. Once a model for a process has been developed, various alternatives of this process can be analyzed easily. Therefore, questions like "How much more can I produce when using one more fork lifters?" can be quickly answered. Thus the modelling and analysis of material flows are of particular importance. In this context programs like *eM-Plant* and *eM-Workplace* from *Tecnomatix* or *Taylor ED* from *Enterprise Dynamics* are used in order to support the above mentioned planning process. However one drawback of these systems is the little intuitive user interface. Normally well-trained users are required, so that the development of complex simulation models requires a lot of time.

In this context the headwords *Digital Factory* and *Virtual Production* describe a new approach to manage these challenges. This is done by creating and analyzing computer models of the planned production systems in the early stages. Results are the identification of planning errors to save time and to avoid rising costs. Here the discrete simulation of the behaviour of the production facilities has a predominant impact. Currently those simulation tools require excellent trained users so that the creation of the complex simulation models is coupled with huge time constraints due to the traditional not very intuitive WIMP (Windows, Icons, Mouse, Pointer) interface.

In conclusion an urgent need can be identified to develop a wearable device, which allows the end users to access production related data every time and everywhere. Furthermore it becomes obvious that the current interface to the computer as well as to the software and databases has to be improved in order to allow even not trained users the information retrieval about the product and the corresponding production processes. Finally it has to be ensured that the developed solution can be easily integrated into the existing IT infrastructure, the used software and databases and the established workflows of the company.

Today’s requirements in production process efficiency combined with their increasing complexity represent a great challenge for staff members at all levels (from the assembly worker to the plant manager). The ultimate goal is the fine-tuning of the production process to perfectly fulfil customer orders and to keep the overall efficiency at high levels.

Within the wearIT@work project, the production pilot team is following its own methodology: namely an initial requirement elicitation process with real end-users, usability tests with local users close to the research team, and final validation with final end users. It must however be mentioned that it is nevertheless very difficult to get hold of the real end users in a global company where production is highly dependent upon human resources.

# 5 Covered Production Scenarios

Through scenarios based on real situations, and tested in a real industrial environment (a Škoda car manufacturing production plant), the wearIT@work project demonstrates how wearable technology can allow an efficient, successful working environment by providing ubiquitous, mobile access to production process-related information where and when necessary: at the shop floor, at the assembly line, and at the manufacturing workstations. This allows workers at different levels to improve the training process of inexperienced workers, to improve availability of information, to speed up localisation and detection of areas to be repaired or maintained as well as to improve communication and knowledge sharing.

## 5.1 Training

Usually the training of employees is done by imparting theoretical knowledge and practical trainings. The theoretical content is represented by paper or electronically (as PowerPoint slides, videos, etc.). Then the practical training is performed under the supervision of a trainer who analyses the single work steps, suggests improvements and indicates errors.

Compared to stationary computer systems, mobile- and wearable computing technology have seriously caught up in performance, functionality, scalability. This makes training solutions based on mobile- and wearable computing an attractive consideration for industrial organisations. In this sense, one of the objectives of this scenario was to supplement the training procedures at Škoda with a context-sensitive wearable computing solution. The wearable system was used to recognize the context of performed work, and as a result provide the trainee with the required information to adequately perform individual assembly tasks. In parallel the wearable computing system tracks the trainees' activities and analyses them. While the workers perform their training, the supervisor is connected to all active wearable systems via his PC, and can monitor all activities.

The nature of the assembly activity itself made it necessary to design a system that does not restrict workers' freedom of movement, while allowing them to handle all necessary components and tools. It was especially crucial to take into account that workers had to adopt many different postures during the assembly process: crouching, standing, seated, inside- and outside of the car. The chosen setup does not introduce much additional effort on the user, because accessing required information is done without or only with minimized explicit interaction with the system.

The usage of wearable computing in this scenario will result in a reduction of training time for the individual trainees, because the wearable system can provide an individual and context related advice to the trainee in real-time considering the predefined media type and the trainees learning process. Furthermore an integrated wearable computing solution will allow a decentralised training and control of the trainees so that a 100 % availability of the trainer on site is not required anymore.

The aim of the first experiment was to extend the initial findings of the experiment made with the workers of Škoda at Vrchlabi. The intention was to measure the acceptance of the system. Besides, the performance in terms of memorability (how fast workers get trained), and in terms of task completion (time consumed and errors made). All in all 40 workers were recruited and divided into two groups of 20. With the first group of workers the aim was to measure and compare their performance in doing an assembly activity while they accessed explanatory paper-based information, and when this information was accessible through wearable technology. The workers tried to perform the complete assembly task as fast as possible and only once.

By means of the second group of workers it was intended to evaluate how wearable technology can contribute to the training process. A prerequisite was that the workers had to learn how to complete the proposed activity. This involved that they had to perform the full process, until they were able to perform the activity without any kind of support. As the "short-term memory factor" was to be measured, the workers had to perform the same task one day later, without support.

In both cases the workers had to perform the experiment twice: once using paper- based support and second using one of the three interaction modalities which were proposed randomly: textile keyboard attached to the sleeve, speech commands and non-explicit or context based interaction.

According to the UCD approach we follow in the project, several experiments were carried out with a representative number of workers at local premises.

The aim of the first experiment was to extend the initial findings of the experiment made with the workers of Škoda at Vrchlabi. The intention was to measure the acceptance of the system. Besides, the performance in terms of memorability (how fast workers get trained), and in terms of task completion (time consumed and errors made). All in all 40 workers were recruited and divided into two groups of 20. With the first group of workers the aim was to measure and compare their performance in doing an assembly activity while they accessed explanatory paper-

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In summary the main findings were:

- Users improved their performance when using the wearable system with implicit interaction: The assembly tasks were performed faster and with less error. In fact, it took 67 seconds less in average than when paper-based information was used which was actually the second best alternative.
- Users did not learn faster using a wearable system. In fact, people were able to learn faster through paper-based support. Although the difference was neglectable when compared to those using context based interaction.
- In the test performed the day after, paper-based learning performed the best, while context-based interaction performed the worst.
- Voice recognition-based interaction was the preferred interaction modality by workers.
- Workers preferred graphical information to text.
- Workers found the system very useful when doing a complex task, allowing hands free access to information, avoiding dispensable movements in order to check information

## 5.2 Final Assembly – Quality Assurance

The quality assurance is part of the quality management and assures the compliance with the quality standards. This allows the company to maintain a defined quality of the product – and not to optimize it. Within the series production this is implemented by using quality KPIs (key performance indicators). The quality management defines methods which are necessary to achieve the required product quality (determination of test procedures, sample size, communication flow in case of detected errors, training of the quality assurance staff, etc.). The quality assurance secures the keeping of those defined actions. The final testing covers the comparison of the measured values with the predefined limit value as well as the classification of the corresponding inspection result (rework, rejection).

A wearable system can support the quality assurance by recording of the performed quality checks and documenting the corresponding results. Areas of interests are: discrepancy of components on the assembly line, the alignment of the components and their fittings, control of the correctness and completeness of operation sequences as well as simplification of the work procedure. Afterwards the recorded data is forwarded to the corresponding responsibles in order be analysed and to initiate corrective actions within the final assembly. Besides, we have identified the process of reporting any detected fault, one of the possible topics where wearable technology can be applied in order to facilitate the work of operators, eliminating the need to handle some piece of paper during the full checking activity and reducing the mental workload associated to report fulfilment. In this scenario the wearable computing system will document all performed actions and quality checks automatically. Furthermore the system will safeguard that all required quality checks are performed.

# 6 Context Detection

In the first phase of the project the aim was to create a wearable system that supported the training process in the learning island. This first prototype formed the basis to evaluate the different modalities of interaction with the assembly line workers under real conditions in the Škoda production site at Vrchlabi, Czech Republic. The front headlight assembly process was selected as a test case since this specific process represents a complex enough task which justifies the use of wearable technologies during training.

In order to track the progress of the headlight assembly, sensors were integrated on distinctive parts of the car body, on the worker, and also on the tools. This allows a detection of sub-tasks which are relevant for the different steps in the workflow. On the user's side a RFID and an inertial sensor package reader has been attached on the back of the user's hand. With the information coming from the RFID reader, required tools such as two cordless screwdrivers can be detected and uniquely identified. The inertial sensors provide are used to pick up the incidence of the torque limiter of the cordless screwdrivers, which occurs when a screw is properly tightened according to the chosen torque.

On the car's side the correct positioning of the assembled car components is monitored by a set of stationary sensors mounted directly on the car body. Critical locations with permanent contact to the component, e.g. the contact surfaces behind screws, are monitored by measuring the force exerted on force sensitive resistors on these surfaces. At locations where the assembled components do not touch the car body, magnetically triggered reed switches are used. They also measure the proximity of alignment checking tools used at specific places for quality control.

As wiring up the worker would be too great an impediment for the user during his work, all data streams from the wearable sensors are transmitted using Bluetooth modules. The data streams coming from the wearable sensors on the user and the stationary sensors inside the car body are gathered and further processed by the Context Recognition Toolbox (CRN). This software framework provides a library of data processing algorithm modules frequently used for context recognition, and allows setting up a process network using these modules.

Figure 1 shows the network, which has been used for the context detection. The left part comprises the processing of force sensitive resistors and reed switches. After some signal conditioning, a threshold operator is applied to detect the status of the respective sensor. The middle thread shows the CRN tasks, which are dealing with the RFID reader. On the right side, the chain of tasks is depicted which detects the occurrence of the described torque limiter [Stiefmeier, Lombriser, Roggen, Junker, Ogris, Tröster, 2006]. A merger task brings these three streams together and sends it to the JContextAPI using a TCP/IP connection.

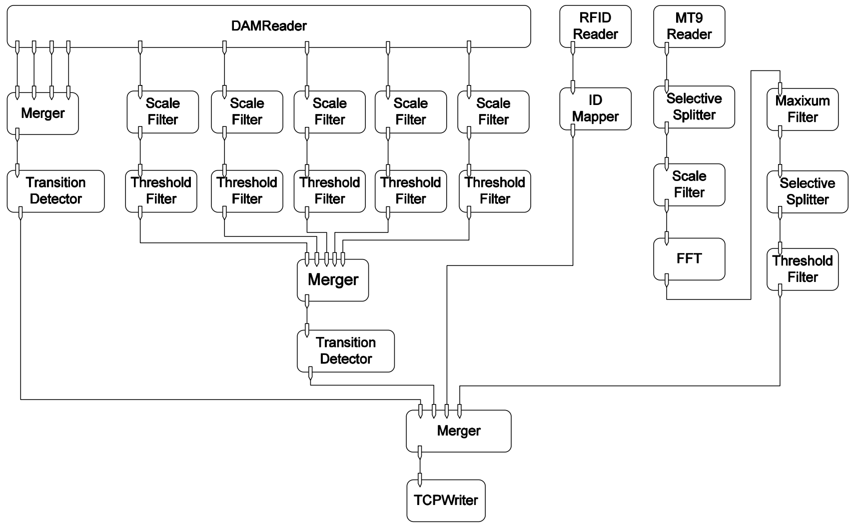


Figure 1: Network used for the context detection [Martua, Kirisci, Stiefmeier, Sbodio, Witt, 2007]

# 7 Used Software Framework

The current prototypes are based on a distributed architecture using several components from the wearIT@work framework. The end-user application is written in Java. The application runs on the *OQO*, and it relies on the *Open Wearable Computing Framework* (OWCF). Specifically, the application uses the following *OWCF* components: *Wearable User Interface (WUI)* and *JContextAPI*. The application is modelled internally as a finite state machine: each state corresponds to a specific task of the assembly procedure for which the user is being trained; transitions are triggered by user actions, both explicit (for example voice commands) and implicit (i.e. actions that are performed as part of the assembly procedure, and that are detected and recognized automatically by the system). The application is capable of tracking the sequence of user's actions, and to monitor that such sequence corresponds to what is expected in the assembly procedure. Whenever the user performs an unexpected action, the application displays a warning message, and can contextually provide appropriate help to support the user.

The user actions are detected through a set of sensors, whose data are collected and processed by the PASSAU UNIV. context toolbox. *JContextAPI* is attached to the PASSAU UNIV. context toolbox [Bannach, Kunze, Lukowicz, Amft, 2006] using the *TCPReaderContextProcessor*, from which it receives semi-elaborated context information. *JContextAPI* perform some aggregation and transformation on the context information received through the *TCPReaderContextProcessor*, and it produces a set of context events that are meaningful and easy to handle for the application. The application simply registers a set of listeners within *JContextAPI*, which notify them of relevant context events representing user actions. The application can therefore react according to its internal logic: checking that the user's actions are in the expected sequence, and, if not, producing a warning message for the user.

The context events produced by *JContextAPI* can obviously affect the user interface of the application, which is built using the WUI component of the *Open Wearable Computing Framework*. Such pilot application is therefore also an example of integration between *JContextAPI* and the *WUI toolkit*. The *JContextAPI* acts also as interface with *the Automatic Speech Recognition System* (ASR) of the *Open Wearable Computing Framework*. The user can in fact issue some simple commands by voice (for example “help”, to request contextual help information). Whenever the ASR System recognizes a voice command, it produces some information for *JContextAPI* (through a dedicated *TCPReaderContextProcessor*), and *JContextAPI* generate an appropriate event for the application. The application can simply register a listener for voice commands, and can therefore react to them taking appropriate actions (for example, open the help page for the current task).

# 8 Current Status of Implementation

The current industrial pilot developed to support the training of the assembly workers shows the trainee how to assemble the parts correctly and which tools and spare parts have to be used (see figure 2). The system additionally detects the single operations by dedicated sensors and gives an error message if parts are not assembled in the correct way and sequence.

Figure 2: Trainee mounting the headlight by using the wearable computer

The *OQO* technical characterises offer enough computational power to fully support the application, and it also allows for appropriate connectivity: network, Bluetooth, external VGA output. The user has a *Carl Zeiss binocular look-around head mounted display* [Brattke, Rottenkolber, 2005], and a *Sony Ericson HBH-300* Bluetooth headset to interact with the prototype application via voice commands. It is necessary to remind the reader that the main navigation mechanism is implicit, i.e. the system detects task completion and goes on to the next step information.

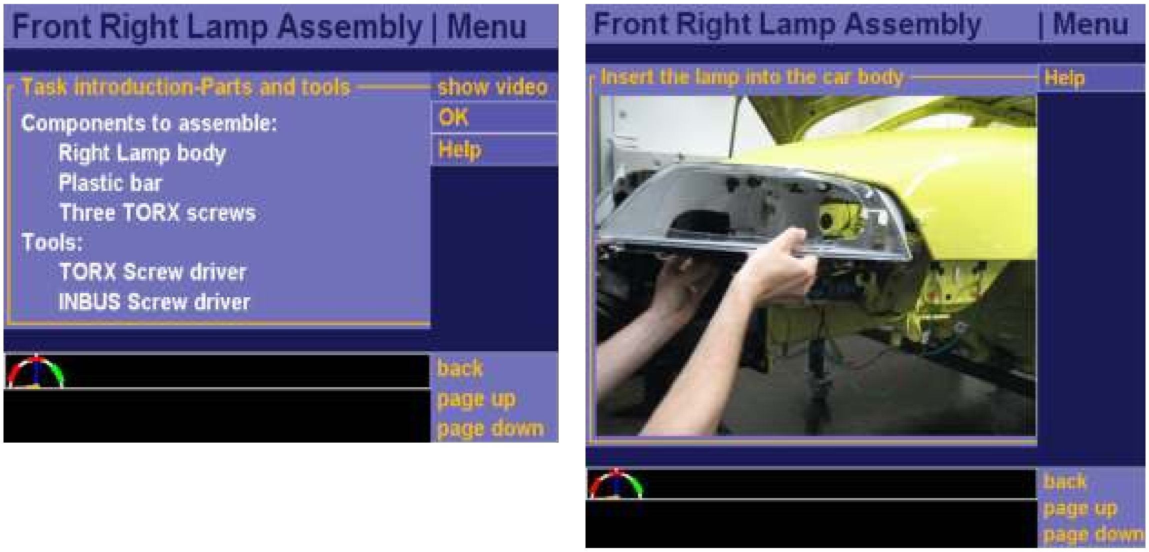


Figure 3: User interface of the application

The tracking of user's actions is enabled by a special data glove that has been engineered by ETH Zurich, and on a set of sensors attached to the car body (see figure 4). The output of the sensors are collected by a stationary system (a laptop), which processes them and make them available for the recognition of user's actions. The application uses WLAN communication between the *OQO* and the computer where the *Context Toolbox* runs. The user actions are detected through a set of sensors, whose data are collected and processed by a dedicated context toolbox. The application simply registers a set of listeners, which identifies relevant context events representing user actions. The application can therefore react according to its internal logic: checking that the user's actions are in the expected sequence, and, if not, producing a warning message for the user.

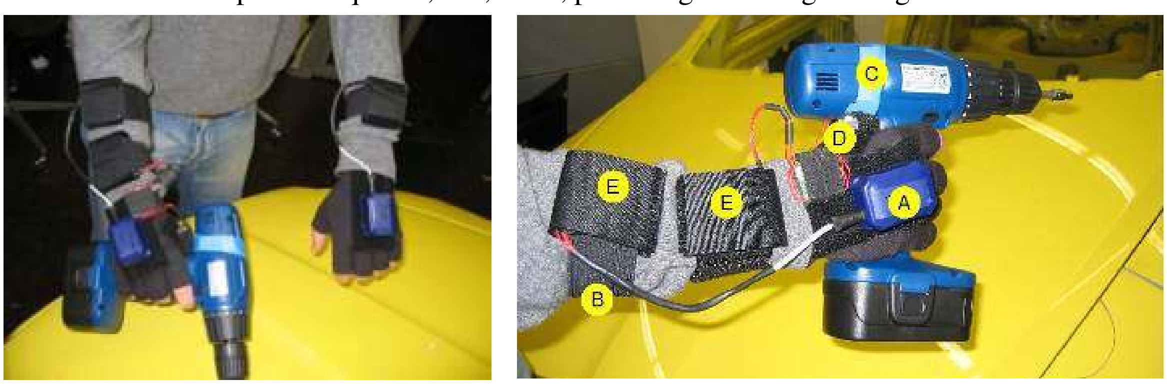


Figure 4: Dedicated sensors are mounted on gloves and tools for the detection of the performed operations

The current production prototype is based on a distributed architecture using several components from the wearIT@work framework. The end-user application (henceforth also referred to as application, for brevity) is written in *Java* and relies on the *Open Wearable Computing Framework* (OWCF), which has been developed within the wearIT@work project. Specifically, the application uses the following *OWCF* components: *Wearable User Interface* (WUI) and *JContextAPI*.

The application user interface is based on the *WUI-Toolkit*, which presents in optimized way the required information to support the user during the steps of the assembly. The *WUI* is specifically engineered to achieve best result in presenting the output on "look around" head mounted displays, and supports very well the state-based architecture of the application: states can be associated with abstract screen structures, each of which will be rendered as the required graphical widgets (text boxes, pictures, menu items, etc.), and the navigation towards other screens. The *WUI* also takes care of building the best rendering of the user interface accordingly to the output device. For this, the envisioned interface capabilities are described with an abstract model independent of any specific interaction style or output medium; implementing a separation of concerns software approach.

## 9 Conclusion and Further Work

The current results of the wearIT@work project show how wearable technology can allow an efficient, successful working environment by providing ubiquitous, mobile access to production process-related information where and when necessary. The developed wearable computing prototypes enables a context-sensitive provision of necessary information to the workers. The wearable solution was able to track and analyse the user's actions, while providing them with actions for error handling or by recording the performed quality checks and documenting the corresponding results.

In the usage of wearable computing solutions for supporting training procedures and documenting the performed quality checks, high benefits can be expected. However, at current stage there is not yet enough experimental data to draw clear conclusions on further benefits and issues of the proposed solution. Therefore the next steps will contain the refinement of the solution according to end-users feedback, and the conduction of further tests and field studies within Škoda in order to gather enough knowledge to evaluate the prototype more comprehensively.

**Acknowledgement**

This work has been funded by the European Commission through IST Project *wearIT@work: Empowering the mobile worker by wearable computing* (No. IST-2002-2.3.2.6). The authors wish to acknowledge the Commission for their support. We also wish to acknowledge our gratitude and appreciation to all the project partners for their contribution during the development of various ideas and concepts presented in this paper.

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# Wearable Computing in Healthcare – from an idea to a working system in daily business

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**Abstract**

This paper describes experiences of a three year effort to develop, deploy, and evaluate a wearable staff support system for hospital ward rounds. All started with workplace studies and staff interviews and the resulting requirements. A wearable system was developed on the basis of those requirements. It consists of a belt worn PC (QBIC) for the doctor, wrist worn accelerometer for gesture recognition, a wrist worn RFID reader, a bedside display, and a PDA for the nurse. The system was evaluated in a living lab environment. There simulated (with dummy patient) ward rounds with 9 different doctors and accompanying nurses were performed. In this living lab with the doctors and the nurses a new system version was designed for deployment in a real life 'production environment'; doctors and nurses performing ward rounds with real patients. This again led to a further improved next generation system used in a two week test deployment in a real life hospital setting.

**Keywords**

Wearable computing, applications, user centred design, living labs

## 1 Introduction

Hospitals are complex, yet highly structured environments where electronic information collection, processing, and delivery plays a central role in virtually all activities. While the introduction of electronic records has improved quality and enabled more efficient information exchange between institutions, it has in many ways actually complicated the work of the hospital personnel. The core of the problem lies in the fact that complex interaction with a computer system is not possible during most medical procedures. Clearly it is hard to imagine a doctor dealing with a notebook or a PDA during surgery. However even during simpler procedures access to computers is problematic. This is due to several factors. First of all, examinations are often performed on thigh schedules with doctors having just a couple of minutes per patient. Quoting one of the interviewed doctors they want: 'time for the patient, not time for the notebook'. Second, the patients expect doctors to devote their full attention to their problems. Retaining the 'human touch' and showing concern were major issues voiced by doctors interviewed in our work. Thus doctors are reluctant to interrupt the examination and focus on a computer instead of the patient, even if it is only for a very short time. Finally examinations require hands to be sterile. This means that hand based I/O devices (mouse, keyboard, touchscreen etc.) are not feasible in between examination steps. As a consequence of the above issues electronic information access is severely restricted during dealing with patients. Patient data is often simply printed out before a procedure and taken along in paper form. Information is also rarely entered directly into the system. Instead it is entered into dictating machines, written on paper by accompanying nurses, or even stored as 'mental notes'.

## 2 Objectives

This paper describes the results of a three year long effort to develop, deploy and evaluate wearable information access system for hospital staff. The work has concentrated on so called ward rounds, which are crucial to all hospital activity, and impose particularly stringent requirements on mobility, unobtrusiveness and cognitive load issues. The work described in this paper has been developed within the EU funded wearIT@work project [1].

The objectives of the research was to identify appropriate ways to improve the ward round concerning a reduction of back office work, increasing the time the team spends at the patients bed and the quality of documentation in the hospital information system by avoiding steps like output on paper and input of notes taken during the ward round.

## 3 Methodology

Applications for scenarios like the above described ward round are discovered by providing users systematically with specific information on new mobile and wearable computing technologies. The initiation of a dialogue between users in healthcare and developers of mobile ICT-solutions which eventually lead to a development of innovative applications is the essential objective of this measure.

Furthermore the different actors in the value chain must be identified:

- Users in healthcare (experts in the application domain)
- Developers of conventional ITC-solutions for healthcare
- Producers of medicine technology
- Developers of mobile ITC-solutions (experts in developing mobile solutions for other application domains)

At the beginning the users are interviewed about their mobile activities, needs of communication, and situation-based information. The aim is to ascertain the specific requirements for mobile solutions. During these interviews the interlocutors talk about their fields of activities and their general working environment. They are asked about the actual state of (mobile) ICT systems being used in their daily work routine and about useful possibilities to establish new mobile applications or how to basically improve the overall efficiency of important and often accomplished tasks. These conversations usually lead to further contact persons.

In the second phase, the results are used to motivate representatives of each actor group for a discussion about ideas for mobile solutions gathered from the interviews and from the results of the study. This information is used to invite prospective users and developers to several events: a start-up presentation to introduce the purpose of the measure and the forthcoming events, and topic-centred workshops which are organized according to the requirements of the participants. Invitations are sent out to further contacts resulting from interviews.

In the wearIT@work project the approach was applied at the Gespag hospital in Steyr/ AUSTRIA with their suppliers Systema and SAP.

## 4 Results

In the wearIT@work project the demonstrator shown in Fig. 1 was developed based on the method described above in close cooperation of all stakeholders like users (nurses, doctors), the

IT-department, the hospital management, the legal department, and the different suppliers and developers as a first prototype within the first 18 months of the project.

The demonstrator was based on COTS (commercial-off-the-shelf) components except the interaction wristband of the physician and the HCI (Human-Computer-Interface) the nurse uses on her PDA. All other devices were part of the existing hardware and software infrastructure at the Gespag hospital in Steyr/Austria. A bedside screen was set up to be used for the entertainment of the patient, however allowing the physician via WLAN to access the hospital information system (HIS).

The patient wears a wristband with a RFID tag. In the first approach the physician used the QBIC belt-computer with WLAN access (www.wearable.ethz.ch/qbic.0.html), a headset for speech input, a wristband with a RFID reader, and a motion sensor. In this way the physician's hand could be kept fumigated while operating the systems. The nurse used a PDA with WLAN access to the HIS (hospital information system).

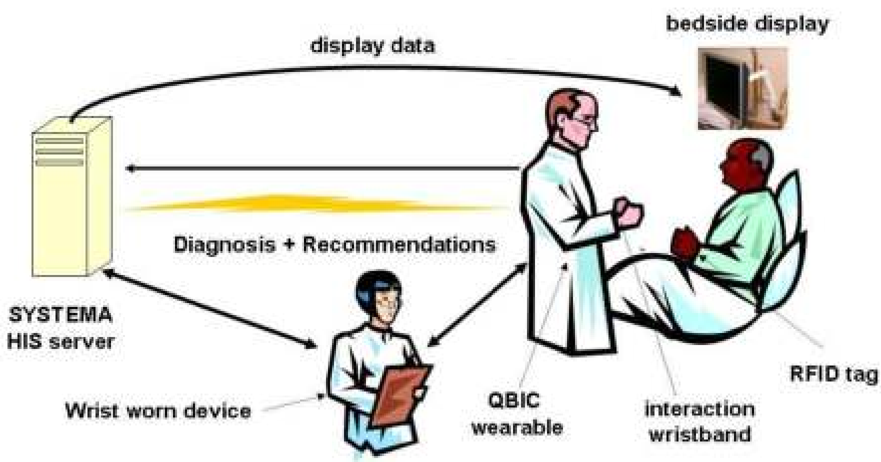


Figure 1: Healthcare demonstrator

The operating process was as follows: When the physician approached the patient's bed the bedside computer gave access to the HIS. By approaching the patient's wrist the patient's HIS data were displayed on the bedside display. The physician could interact with the HIS by gestures monitored by the wristband and interpreted similarly to a mouse input. By speech input the physician could place orders for the nurse processed at the patient's bedside while the physician authorised the nurse's input by simply being in the vicinity of the nurse. For the wearable device of the nurse a HCI as a further layer of the order management system was developed (see Fig. 2).

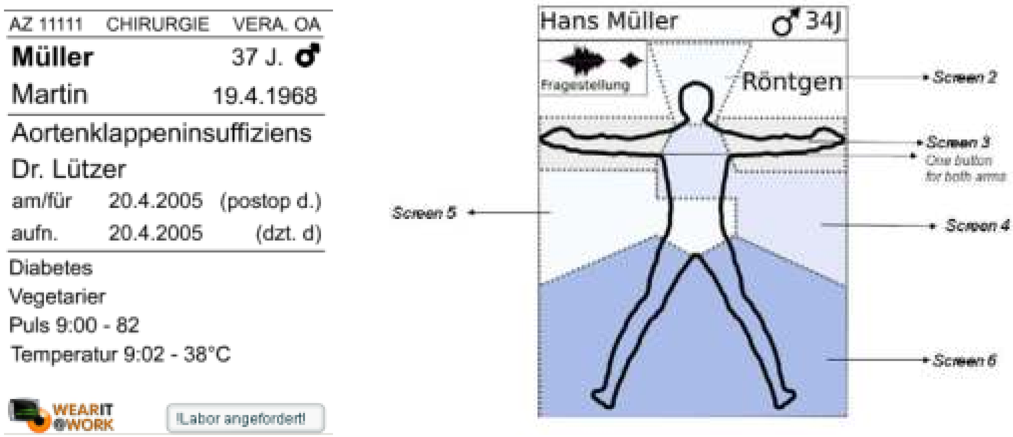


Figure 2: Examples of the PDA HCI for the lab and X-ray order management

The first reactions of the end-users (physicians and nurses) and the management (CIO and CFO) were very positive as this solution reduced media conversations, increased the data quality, and used the existing IT infrastructure. However, issues like replacing the signature of the physician on a medication by the proximity of the physician and the nurse at the patients bed are pure organisational but essential for a successful introduction of the wearable computing solution envisaged. It was decided to take this into account as an organisational action item when planning a role out of a final solution.

To ensure that the new technology of gesture interaction for navigating the document browser situated at the patient's bed works also under hospital conditions and not only in the lab environment, tests were performed with a group of students. The focus of these tests was to ensure the required robustness of the solution.

Based on these tests an improved solution especially for the gesture recognition was developed and tested by ten teams of a nurse and a physician in the Gespag hospital in Steyr.

## 5 Lessons Learnt

It became clear that an easy to learn and robust gesture recognizer is the key for a successful introduction of a wearable computing solution. Such it was found that in case the activation of functions had been done by separate gestures users performed better than if activation of functions was integrated into other gestures. In comparison with audio feedback the users preferred visual feedback on the output screen. We also learned that well planned training has to be performed with clinical personnel for a successful system introduction.

After these tests the end users in the hospital gave an overall positive feedback on the potential with regard to work efficiency by immediate entering and authorization of examination requests resulting in less errors and the avoidance of redundant work. However, there is the clinical personnel's fear looking like fools in front of the patient performing strange gestures. The doctors claimed for physically smaller and socially more natural gestures.

The analysis of the social aspects identified as a main advantage the more efficient work of doctors and nurses during the ward round, together with the related gain in time used for personal care to patients, and the more accurate documentation preventing mistakes and errors.

Concerns were expressed about the system enabling learning to patients and less independent personnel by a calmer organized ward round. Previous experience in other IT projects had left a bad taste and concerns related to the introduction of new IT solutions. Therefore the social scientists in the team recommend the implementation of wearables in a non-coerced form, introducing the new information technology emphasizing the positive effects of the system accompanied by extensive user training.

Requirements were derived regarding the future innovation cycles. The future system should enable nurses to access more information and navigate through the clinical information system during the ward round and should follow a set of codes and norms for users of the wearable devices. The stakeholders lined out more research should be invested to the views and needs of patients in this context.

## 6 The Next Generation

Based on the above findings a next generation prototype has been designed and implemented. A major aim of the implementation has been to facilitate deployment in real life 'production' ward rounds with real patients, as opposed to simulated ward rounds in the evaluation described in the previous section. Such deployment is currently under way and an initial two week test was completed.

Compared to the first generation prototype the system has been modified. It has been integrated with the existing hospital information system and its back-end technology. This has involved major software restructuring to make it compatible with the requirements. It has also leaded to a modified network structure and application distribution. The hardware has been modified for increased robustness and the gesture recognition has been improved according to the findings of the previous prototype evaluation. The improvements include new and less obtrusive activation gestures, as well as extensive fine tuning of the recognition algorithms. a proximity detection system has been integrated to provide the contextual information about which persons (doctors, nurses) are taking part at each ward round. Pictures taken by the nurse (e.g. of wounds) with her PDA are automatically attached to the patients files in the hospital information system (just like the sound notes in the old system).

Also the hardware was modified. The wrist worn sensor modules were redesigned and re-implemented. A new RFID reader with improved range and higher reliability ensures an easier and more accurate retrieval of patients identifiers, and the Bluetooth based communication module got an improved battery, charging circuits, battery and function indicator and an external switch. The whole wrist band became more compact, easier to wear, and more nicely-looking. Also the main processing unit worn by the doctor has changed from the QBIC system to a NOKIA 770 as a 'mainstream', commercial device. An RF-based proximity detection system has been implemented and integrated, based on TecO Particles [2] attached to the badges of the hospital personnel.

The overall software architecture of the prototype got two main end-user applications: the MPA client application, which is used by the doctor to access the Hospital Information System (HIS) and the custom PDA application, which is used by the nurse to support her work during the ward round.

The MPA application (which is part of the hospital information system in Steyr) is provided by Systema (a partner of the wearIT@work consortium). It is a client- server application, which does not only allow the doctor to access all patients data, but also to order examinations, and to manage a number of other tasks related to daily activities. In our scenario, the front-end client of the MPA application has also patient's trust in staff.

# 7 Conclusions

None of the patients interviewed felt such a system would have an effect on their relationship with staff, as the system will not prevent them from talking to the doctors and nurses. The patients interviewed stated that they would be happy to see such a system working in the hospitals in the future.

Despite intensive lab validation before the deployment, technical problems have invariably emerged during the test. Thus the person independence of the gesture recognition was not satisfactory. While the gesture recognition worked fine for one of the doctors (as well as for test persons in the lab), the other had major problems handling it. The procedures needed for system initialization and user registration were not robust enough. Obviously in many cases switching devices on/off, registering users, and coming into/out of range of Bluetooth nodes has been performed in sequence and at speeds which were not considered in the lab trials. This often caused components to freeze. Similar problems were caused by issues with wireless links. In particular when there were many people in the room (e.g. to view a demonstration of the system) Bluetooth links or the proximity detection signals would be blocked. In addition the way doctors were handling the wrist worn RFID reader combined with the new mounting often resulted in occlusions of the Bluetooth communication.

Interviews with two doctors, one of whom participated in the tests, and one who did not and spoke generally about working conditions and potential changes due to wearable computers. Additional interviews were conducted with two patients, who used the system during their stay, and with the hospitals technical specialist, who worked on servicing the system before and during the tests. The staff reactions were strongly overshadowed by the technical issues described above. Clearly the problems with gesture training were, like in the first prototype, a key issue, and people suggested that speech control might be better.

The fact that the system allows hands to remain sterile was nonetheless seen as positive. The patients were positive about the system. They stated that seeing the results on the screen and having them explained in real time by the doctor increases patient's trust in staff. None of the patients interviewed felt such a system would have an effect on their relationship with the staff, as the system will not prevent them from talking to the doctors and nurses. The patients interviewed stated that they would be happy to see such a system working in the hospitals in the future.

An improved version of the system is actually under evaluation in the gespag hospital in Steyr/Austria.

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# An Approach to Systemic Innovation of Information Technology for Emergency Response

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**Abstract**

This paper reflects on the design challenges related to designing novel information technology for the domain of emergency response. The reflection is grounded in the concrete design objectives of a major European R&D project focussing on the novel information technology of wearable computing. Based on a concrete discussion of these challenges, the design objective is framed as supporting the systemic innovation of the socio-technical system composed of technology, users and their organisation. A number of specific design techniques used in the before-mentioned project are critically discussed in terms of their contribution to such a systemic innovation.

**Keywords**

Wearable computing, applications, design, innovation

## 1 Introduction

The wearIT@work project had defined as its leading goal: "Broad industrial acceptance and application of an empowering wearable computing reality in 2010" [1]. While this sounds like a pretty ambitious goal, the project also had considerable resources to spend on this. To give you an idea, for the 4.5 years duration of the project, each year the 36 partner organisations had 37 person years to spend.

With the project finishing at the end of this year, it might be a good time to take a first look back. This paper tries to offer one perspective on the objectives and approach of the wearIT@work project. Without a doubt there are numerous different perspectives for this and similar projects. This one is based on the author's role as a co-author of the proposal and his efforts in leading the design process for one of the four application fields of the project, namely emergency response.

The goal stated above is quite in line with the expectations the European Commission had set for this type of project, called Integrated Project, of which wearIT@work is an example. Generally speaking, the expectation was to achieve breakthrough results in the broad application of a new type of technology by putting a critical mass of people to work on the task for a considerable amount of time. It would be a helpful endeavour to look at this expectation from an organisational point of view by studying several similar projects to understand whether and to what extent projects of this size and composition are suited to produce the desired results. But this is not what this paper tries to achieve.

Looking at the goal of wearIT@work, there are certainly many reasons that let the consortium to adopt it and that let the European Commission to co-fund this project. In the following, one possible explanation of this is presented that will help in understanding the stakes and expectations and it will also help in framing the design challenge defined later on.

Presumably there are two main ideas that let the European Commission to co-fund the wearIT@work project. The first concerns the productivity of the European workforce. The quite general idea is that Europe has a qualified and skilled, yet relatively expensive workforce the continued existence of which can only be ensured through increased competitiveness. This, in turn, may favourably be achieved by enabling workers to leverage their skills in a more productive way by using information technology. A popular way of saying this is that workers may become empowered through information technology.

The second idea relates to the specific technological area called wearable computing. As the name suggests, it must be possible for this type of technology to be worn like or as easily as clothing. But the key concept behind this is that a wearable computing system must be designed such that it can be used while carrying out some other activities and not instead of them. Based on this, the idea is that wearable computing can support skilful work processes as they are being carried out, hopefully increasing the workers' productivity. An important aspect regarding wearable computing is the level of maturity that this technology has reached today. While the first wearable computer reportedly was conceived in 1955 [2] and many of the underlying technologies have become generally available in recent years, very few successful professional wearable computing applications existed when the project started. So from a technological point of view it seemed the time had come to investigate a more general professional application of these technologies.

By putting the two above ideas together, the assumption quite obviously is that wearable computing may provide the required productivity gain to the European workforce. The particular thing about this is that the gain is not supposed to just come from wearable computing as such, in the sense that this technology could perform some task faster than a person could. Instead, the gain is supposed to come from the amplification it can achieve for skilful work processes. There are a number of benefits that might come from this. For one, the worker can apply his skills and expertise throughout the process of carrying out the task, allowing for the level of flexibility that is typical of skilful labour. The alternative consists in analyzing some skilful activity and designing a technology that can carry it out instead of the worker. This is often possible to a certain degree but existing systems do not expose the level of flexibility to adapt to changing conditions as expert workers do.

It is important to realize that performance is only one and maybe not the most important factor in this line of argument. It is clear that for some cases wearable computing is very likely to increase productivity. The more interesting potential though lies in the intimate support of skilful work processes. Independently of a possible direct increase in productivity, this potential relates to the capacity to apply these new technological tools to changing conditions with the same flexibility known from expert skills. In this sense the technology can be seen as an asset to a sustainable development of work. And in this sense it can be meaningful to call wearable computing an empowering technology [cp. 3]. On the other hand it is quite dangerous to mistake this potential for a reality. Whether a given company will decide to use wearable technologies in this way is by no means certain. From an economic perspective and depending on the type of work, a company may in fact decide to use wearable technologies to have less-skilled workers carry out the same tasks previously done by higher-skilled workers, capitalizing on the assumed productivity gain associated with using the technology and effectively devaluating human labour. As with all technologies, the actual meaning of wearable computing will be defined by its concrete use in a given application field.

These two ideas then provide a vision and purpose for the research and development work to be conducted in the wearIT@work project. This is a very useful thing, at least for an applied research project, as it provides a reference for the questions to address and research to carry out. As an example, one of the major obstacles to professional use of wearable systems to date is poor autonomy, i.e. insufficient runtime of devices for today's energy sources. While the problem of energy sources must be solved in order to arrive at usable solutions, this problem is obviously largely irrelevant to the question of how wearable computing could bring the societal benefits outlined above. Therefore, the wearIT@work project did not address basic technological questions such as energy consumption but tried as much as possible to focus on exploring the specific potential this technology could bring to a broad professional application.

This paper concentrates on the approach that we applied for this exploration in the application field of emergency response. In the next section, the general motivation and objectives of this exploration are explained. Then, the methodology is presented and critically discussed against the objectives outlined before. The subject of this discussion is not the design or artefact that may result from the methodology but the specific qualities of the presented techniques in terms of systemic innovation as explained in the next section. An example for a concrete design that resulted from this process can be found in [4]

## 2 Objective: Systemic Innovation of a Socio-Technical System

When considering the domain of emergency response, many problems can be identified quite easily that are candidates for support by wearable computing technologies. For example, fire fighters may frequently get close to the limits of their physiological capacity during interventions. This is due to physically highly demanding tasks such as carrying out victims while using heavy equipment, including a breathing apparatus, in hot and hostile environments. The resulting exhaustion is dangerous as it may reduce the fire fighter's ability to make the right decisions and carry out the required actions in time to conclude the mission safely.

It is therefore not surprising that wearable sensors have been proposed to monitor the health condition of fire fighters and, in case of a critical condition, use other wearable technologies to signal an alert and communicate it to fellow fire fighters [5]. Such a support is indeed likely to provide a considerable benefit and related research and development is therefore very appropriate. Nonetheless, looking closer at this example also shows that this case is not as clear-cut as it may seem, in the sense that there is a problem that can be identified relatively easily and for which a technological system can simply provide a solution.

To start with, fire services have of course identified the problems related to operational fitness a long time ago and they have taken different measures to avoid or handle them. The most basic measure is physical training and frequent tests of physical aptitude to ensure a certain level of operational fitness. While this may seem trivial, it is in fact important because fire services do expect very high peak performances for short stretches of time during operations. And this makes it difficult to decide whether a fire fighter's condition warrants an alert or whether it is still in an acceptable state. Moreover, fire services have established rules of engagement for missions under breathing apparatuses, including maximum mission times and minimal recovery periods. And to make sure that these rules are actually observed, the dedicated role of security officers has been created. On the command level, group leaders are trained to assess the operational fitness of their team members and only assign such missions that can be carried out safely. Finally, in terms of technological support, many fire fighters already use Personal Alert Safety Systems (PASS) that typically produce a high-volume sound after being activated manually or automatically. Today, fire fighters routinely rely on the effectiveness of these measures to engage in missions under life-threatening conditions.

The point here is that any potential wearable system for monitoring health conditions and distributing alerts is confronted with an existing status quo consisting of fire fighters that have learned to do their job, an organisation that has set up and structured the work, and tools and technologies that support the work, all in such a way as to ensure safe and effective operations. For designing such a wearable system for health monitoring, this status quo is relevant and important in several different ways. Most obviously, detailed knowledge of the status quo can help designing a system that is actually usable given the requirements and constraints of the status quo. But most frequently, there is no optimal match between a new technology and the current status quo. As a consequence, the technologies will either not be used to their full potential or there will be a change of the status quo towards a better fit. In the case of a wearable system for health monitoring, one of the potential problems is that such a system can not only be used to increase safety during operations but also to identify general health problems, possibly related to a bit too little physical training or a bit too much alcohol. Even though this functionality may not be part of the original vision of the system and even though nobody might actually want to use the system for this purpose later on, it will still likely have an influence on how the system is perceived by its users and therefore on how it is going to be used.

This kind of perceived or actual control outside of operational use is but one example of how the meaning of this new technology may only unfold in the course of being used. Another example is the trust in the system's assessment of a fire fighter's fitness that users may or may not build up gradually over time and with experience. And while carefully studying the status quo might help anticipating some of these developments, many will only become visible when putting the new systems to use.

One conclusion to draw from these observations is that the subject of innovation and design is not or should not be only the technology but the entire socio-technical system composed of technologies, people and their work practices and organisation. More precisely, the challenge for successful innovation and design is actually the transition of this system from one status quo towards a new one, where all its parts again match well with respect to its purpose. As this transition typically requires changes to all the interdependent parts of the system, the process has rightly been called systemic innovation [6] of a socio-technical system.

This understanding of innovation and design is of course not limited to wearable computing or emergency response. Instead, it is applicable to any case where a technology has an impact on a socio-technical system. But it is of particular importance for wearable computing and for emergency response. In terms of the technology, the importance comes from the potentially paradigmatic difference in use as explained in the previous section. In terms of the application field of emergency response, the importance comes from a number of special properties of emergency organisations, such as technological conservatism as a risk-reduction strategy, that make the transition of the socio-technical system particularly difficult.

Based on this understanding the design challenge for the wearIT@work project can be framed as illustrated in Figure 1.

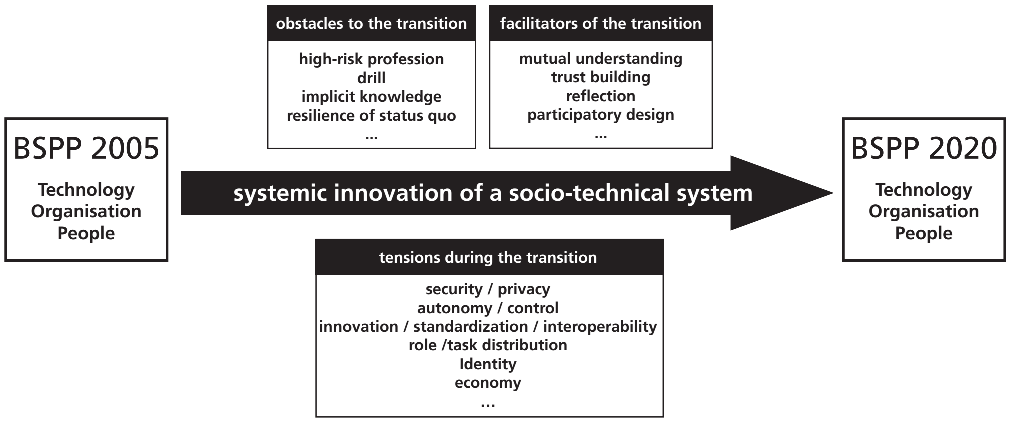


Figure 1. Tensions, obstacles and facilitators for systemic innovations within emergency response organisations

Within this project, the Paris Fire Brigade (BSPP) represented the application field of emergency response. At the beginning of the project BSPP was in a given state regarding its organisation, personal and technologies. Based on past experience, a realistic timeframe for larger scale changes to occur due to the introduction of wearable computing was taken to be in the order of 15 years. In this section, some of the tensions and some of the obstacles relevant for the transition towards a future BSPP have already been mentioned. The design challenge is then to facilitate this transition in such a way that systematic innovation can occur during this transition.

## 2.1 Some facilitating factors for systemic innovation

Figure  also provides a number of factors that can facilitate systemic innovation during the transition of a socio-technical system towards a future status quo. The most basic step consists in establishing a mutual understanding between the involved actors. While it may sound trivial that the prospective users need to understand the technology and developers need to understand the work of the users – both to some degree – the reality of many projects is that only very poor or clichéd shared understanding is achieved. Moreover, there are pragmatic and inherent limits to this understanding. Pragmatic, because both developers and users can only invest so much time in understanding the application domain and technologies, respectively. And inherent, as explained earlier, because the meaning of a given technology for a given application field is likely to evolve during use. Therefore, mutual understanding is something that cannot simply be established at the beginning but is something that needs to be created and checked along the development process.

Related to this shared understanding is trust building. A given technology may or may not be suited for a given problem in the application field. And whether it is suitable or not may only become apparent later on in the development process, possibly after considerable investments have gone into this development. For users to remain critical and creative throughout a development process they must have faith that their feedback will not only be heard but that it has an effective influence on the direction of the development.

Another facilitating factor for systemic innovation is reflection. As was explained earlier, the impact of some new technology on the socio-technical system is uncertain and the direction for the most favourable development may only become discernible in the process. Therefore, it is crucial to enable all actors to reflect on the characteristics and meaning of the available options. Enabling such a reflection is by no means easy. To start with, many technologies are inherently complex, making it difficult to understand and assess their impact. Also, especially in the domain of emergency response, many actors have a conservative and sometimes rigid attitude towards innovations as a result of the risks of the profession and the correspondingly strict professional drill. While such an attitude is often very helpful in ensuring operational safety, it may also become a problem if it limits thinking about alternatives and challenging established assumptions.

Besides understanding and reflection, the actual participation of users in designing innovations is another facilitating factor to systemic innovation. While the approach of participatory design has been applied to information technology for at least 20 years, it holds a number of unique challenges for highly novel technologies such as wearable computing and – for the same reasons mentioned above – also for skill-intensive high-risk professions such as emergency response. In terms of the technology one major problem is that the implementation of a working physical system may take a long time, making it difficult to consider substantially different design options and also to keep users interested in the design process. In terms of the application domain, it is very difficult or almost impossible to try out pre-production systems during actual emergency interventions, which is especially true for fire fighting.

## 3 Approach to Systemic Innovation in wearIT@work

As was shown in the previous section, the tensions, obstacles and facilitators of the transition of the socio-technical system are manifold and interconnected. They are also specific to the user organisation, the technologies and all other parties involved in the design process. Moreover, they may only become visible during the transition.

As a consequence, there is no single abstract design process that can be applied in a straightforward manner. In fact, there is not even one specific design process that can be identified for any given project. Instead, there are several possible design approaches that may accentuate different things, require different skills and yield different results. While one can learn a great deal about advantages and disadvantages of such processes from past projects, it is very hard or impossible to assess beforehand how any one design approach will play out for the specific circumstances of a new project.

Therefore, the specific elements of the design approach should be chosen in the course of the design process, based on concrete experience with the users, the technologies, the organisation and everybody else involved in the development process. And they should be checked and adapted throughout the process to ensure their continued suitability. This continued suitability is crucial because the goal and stake of the design approach is not only to inform product development but also to promote a sustainable and rich innovation process of the entire socio-technical system.

In the following, the major elements of the design approach followed in the emergency response part of the wearIT@work project are presented and explained in terms of their motivation based on initial empirical studies. As explained above, the claim is not that these elements should be part of every similar design process. Depending on the specific circumstances they might or might not. The lesson from this design approach to be considered here is how suitable elements for a sustainable design approach can be derived from an empirical understanding of the design context and what specific benefits and challenges are connected to this specific set of elements in terms of systemic innovation. For more detailed descriptions of these techniques see [7, 8]

As illustrated in Figure 2, the design process started with empirical studies of the emergency response domain. The photo on the left shows the author during search and rescue training


Figure 2: Elements of the design approach followed in the emergency response part of wearIT@work

with protective clothing and breathing apparatus. This was one of many studies, including interviews, observations and also incident command training, that the author conducted to build up a substantive understanding of the design context.

## 3.1 The real thing

One of the insights gathered this way is that fire fighters typically think about new technologies from a very concrete operational perspective. This is to say that they do not typically think about abstract possibilities related to some technology but about the concrete application within their context of use. This is likely due to the practical nature of the profession but it is also a strategy to make sure that there is no potentially dangerous disconnect between the consideration of technological options and the tight requirements of operational safety. To put it very bluntly, most fire fighters will prefer trying out new technologies under realistic circumstances to discussing their possibilities, and most will have difficulties and will be reluctant to utter opinions without such hands-on testing. It is important to observe that this is typically the case but not always. In our studies, for example, we have found that fire fighters that work in specialized departments for e.g. work safety, operational procedures, and – unsurprisingly – telecommunications are quite used to thinking and talking about tools and technologies in more abstract terms. But this specialization also typically goes together with seniority and operational responsibilities higher up the chain of command. And this in turn often results again in a certain disconnect from the practical conditions and requirements of operational fire fighters. Although very rarely, we have also met fire fighters that were highly connected to operation field work and at the same time very capable of and inclined to reflect on and discuss technological options on an abstract level.

When running a design process it is of course highly valuable to find and work with such individuals. But this is a matter of luck and moreover any such individual is not necessarily representative of the variety of experiences and perspectives existing within the user organisation.

Therefore, being able to have fire fighters try out equipment under realistic conditions, ideally during life interventions, is a very desirable option for any such design process and it becomes a necessity when the design reaches a certain maturity. Nonetheless, throughout the design process, it is not always possible or in fact the best choice to conduct such tests under realistic conditions. As mentioned earlier, it may take a long time, sometimes years, before a system based on some new technology becomes sufficiently functional as to be used under realistic circumstances. In terms of systemic innovation it would be completely inadequate to try and fix the goal of some technological development years in advance and wait until the system can be tried in the field to gather feedback on its suitability. This would limit innovation to the initial design phase and would essentially result either in a post-hoc adaptation of the rest of the socio-technical system or in poor appropriation or use of the system. Also, availability of a functional system is not sufficient in itself. The assumption underlying such field testing is that it can yield particularly rich and valid feedback on the actual later performance of the technology during use. But this obviously requires that field tests are representative of this future use along all the dimensions. If the system under consideration is supposed to be used by a number of collaborating actors, representative testing requires a corresponding number of systems. And this is very typically not the case, even if one or two functional systems exist. Besides these issues related to the technology there are other problems that limit the actual usefulness of testing during life interventions. Most importantly, any given intervention is not representative of interventions in general and so successful use during one intervention does not prove general suitability during all interventions. And any given intervention may not exhibit all or even any of the aspects of interest for a given system. So there is an important inherent limitation to the quantity and quality of feedback that can be obtained from this type of testing.

Additionally, observation of usage during life interventions is very difficult or impossible and can only partially be compensated for by post-hoc interviews and other techniques.

But perhaps the most important downside for systemic innovation of testing during life interventions is that fire fighters have quite understandably their lowest availability for innovation. This is not to say that no valuable feedback may come from such testing. But chances are that any flaws of the system, either superficial or essential, will result in a rejection of the entire system. This is because the nature of the situation leaves little or no room for error and therefore does not promote experimental curiosity.

## 3.2 Exercise simulations

Interestingly this situation is not very different from the training of fire fighters. While experience from life interventions is considered a particularly important aspect of professional expertise, even after years of service many fire fighters have not personally experienced many interventions of particular difficulty. Nonetheless, their training is supposed to prepare them for the particular risks and challenges of their profession. To a limited extent this is done by simulating interventions of actual size in possible intervention sites. The benefit of such simulations is to exhibit more or less the same complexity and dynamics of a real intervention. But as with real interventions they can only exhibit a limited amount of features to remain realistic and due to the considerable efforts required they are conducted relatively rarely. Therefore, much of professional training is based on targeted intervention scenarios of limited size and length that focus on selected aspects. For example, one way of training navigation in smoke-filled buildings during search and rescue missions is by blocking the fire fighters vision (Figure , 2$^{nd}$ photo from the right). This is unrealistic in a number of ways. First, it does not consider the heat during a fire fighting intervention which is a physiologically and psychologically relevant factor. Second, smoke does not necessarily block the fire fighters' vision altogether but may leave some visibility, especially just above the ground, which again is a relevant factor for navigation. The point here is that for practical reasons this simplification is considered acceptable and useful for the purposes of training. It is not considered sufficient though, requiring other training techniques targeting different aspects and making different simplifications. For example, dealing with the heat and the correct handling of fire is trained in fire simulators with artificial fire. It is a result of the professional expertise of the instructors to find acceptable simplifications and combine them in a way as to achieve robust and realistic training results.

The lesson to be learned for design processes is that such training exercises afford opportunities for testing technologies under relatively realistic conditions. While this sounds like good news, the problem is that the impact of simplifications on the specific technology or system under investigation is not evident. Based on the design questions at hand, the appropriate kind of training exercise must be carefully chosen and possibly adapted. Nonetheless, there are many benefits to this type of study. Depending on the specific setup many of the usage constraints of a real intervention can be relaxed, making it considerably easier to implement functional systems that can be used during these exercises. Moreover, due to the possibility to instrument the environment of the training exercise, parts of the system functionality may be simulated and detailed observations may be achieved. In the wearIT@work project we have followed this approach by introducing simple functional systems into exercises at the training site of the Paris Fire Brigade. In our experience, such studies can yield very rich and detailed feedback on many aspects of using new technologies. Besides the limitations of realism outlined above, a number of additional difficulties can be encountered that are relevant in terms of systemic innovation. First, as is the case for real interventions, training exercises typically put the fire fighters into an operational state of mind that lets them perform the operational procedures the way they have been trained to. This effect is often amplified by the social configuration of the study. There is a group of relatively foreign scientists and technicians visiting the training facility and observing the fire fighters behaviour during a simulated intervention. This prompts the fire fighters to play things out by the book. In fact, we have experienced that senior officers often feel the need during such studies to guide the fire fighters under their command to abide by regulations or even to act accordingly to the way the officer anticipates the study is supposed to run. Such a ‘good performance’ can of course be very detrimental to the insights to be gained from the study. In a real intervention there is not the same kind of supervision and from all we have heard, things rarely go entirely by the book. For the purpose of systemic innovation what is important is not the behavioural ideal which is defined in the regulations and which is the subject of training. Instead, it is the actual behaviour including its irregularities and in particular the errors and breakdowns that might occur in its course, particularly when dealing with new technologies. Exposing this kind of realistic behaviour requires an openness that is based on shared understanding and trust regarding the design process. This is an excellent example of why building understanding and trust with the user community is a cornerstone to a successful innovation process. And it is also an excellent illustration of one of the challenges associated to the notorious and often over-simplified concept of Living Labs: the productive integration of an authentic context of use with a design and innovation process.

Two things remain to be said about such training exercises. One is that participants may not only be too concerned to do it right. Some individuals have a harder time than others to engage in the training exercise, take it for real to the extent possible and display correspondingly realistic behaviour. This again may be very detrimental to the results of such a study, in particular as disengaged behaviour is rather contagious and makes it harder for other participants to keep their minds on the simulated scenario. Choice of participants might help with this problem but hand-picking or exchanging candidates is often impractical and so designing and conducting engaging studies is another crucial requirement. The second thing to say is that while this section might have given the opposite impression, some participants of such studies are surprisingly capable of engaging into realistic simulated interventions and at the same time trying out and discussing new technologies and modes of use. But, as was mentioned before, this is the rare exception.

## 3.3 Simulation and Play for Innovation

In the previous section we have heard quite a bit about the benefits and challenges associated to testing new technologies in the context of real or training interventions. In our empirical studies we have come across two existing practices of fire fighters that let us to create two additional techniques to address some of these issues.

The first is that fire fighters regularly use building and site maps to prepare, conduct and also to debrief interventions. This obviously depends on the availability of such maps which is not often the case before interventions. But even if no maps are available, fire fighters may draw up simple maps after reconnaissance missions to communicate the spatial setup to their colleagues. Additionally, we have found that maps are also used for training purposes, especially for higher command levels, to conduct a kind of simple intervention simulation to try different tactical and strategic options and reflect on their relative advantages and disadvantages. Moreover, maps are regularly drawn up for interventions of particular interest and used to facilitate sharing experiences and lessons-to-be-learnt.

For our interest in design and innovation the interesting point about this practice is that fire fighters use the relatively poor medium of paper maps for planning, analysing, communicating and reflecting about aspects of interventions. All of these uses constitute simulations of interventions in the sense that in the minds of the participants the intervention unfolds based on the spatial structure provided by the map and otherwise based on their professional experience. In a sense, the simulation happens less on the paper than in the minds of the participants.

Based on this understanding we have created a kind of board game for simulating interventions with multiple actors (Figure , 2nd photo from the left). The purpose of this board game is to have the fire fighters use very simple non-functional systems made of paper or other materials that are easy to work with. The functionality of these systems would either be imagined by the participants or simulated by the facilitators. For the purposes of systemic innovation under consideration in this paper, there are a couple of relevant observations that we made during several board game simulations. The first is that despite the relatively poor medium and obviously limited realism of this technique, the difference to simulated interventions at the training site is less pronounced than one might think. Obviously, the board game simulation lacks mostly all physical aspects of wearing fire fighting gear and moving through a building structure. For the design of wearable technologies this means that many of the ergonomic aspects cannot be investigated by this technique. As we have seen in the previous section though, fire fighters do not necessarily engage in training exercises and therefore may not bring in their professional expertise to compensate for the shortcomings in realism present in these exercises. Conversely, and with the same caveats identified in the previous section, fire fighters may engage quite heavily in a board game simulation, bringing the simulated intervention to life in the minds of the participants. Of course it is not surprising that this engagement might be harder to achieve for board game simulations and that it may break down again more easily. While this calls for preparing and carrying out such simulations more carefully, they still provide an excellent means to simulate the use of new technological concepts at an early design stage.

The undeniably smaller realism of this technique is compensated for by at least the two following benefits that are of particular interest to systemic innovation. First, the low-tech appeal of this technique and indeed the non-intervention setting contributes to an openness of the participants towards new technological concepts and new modes of operation. Maybe this is due to the fact that the presentation of these concepts is less factual and relies more on the imagination of the participants. From our experience, this also requires and stimulates negotiation among the participants to establish a shared understanding of the concepts in order to enable a consistent simulation. The second benefit is that due to the spatial configuration and dynamics of the board game simulation it is easier for the participants to switch between acting out the intervention and reflecting about their actions and possible alternatives. This is a particularly useful benefit for systemic innovation.

Nonetheless there are also a number of downsides with this technique. There is a limit to the intervention complexity that can be simulated with reasonable effort. And the interactive aspects of information technology can also only be simulated to a very limited extent. Moreover, carrying out, observing and analysing this type of simulation requires more or less the same considerable effort as for a training exercise. As a result, this technique is a very valuable complement to the techniques discussed previously, but may only be used for certain design questions and with reserve.

The second practice that we observed is that many fire fighters regularly play computer games as a leisure activity, mostly military simulations with tactical challenges but also fire fighting simulations. There are a couple of interesting things about this. First, this is a voluntary activity outside the scope of their professional life. Second, this is to some extent a collaborative activity, at least in the sense of talking about it and competing for higher scores. Third, and this is somewhat surprising, these games including fire fighting simulations are played by professionals of this domain and not by people that may dream of becoming a fire fighter. In short, even though these fire fighters have the opportunity to experience the real thing in their professional lives, they still find computer simulations sufficiently attractive to engage in them. Our current studies do not yet enable us to explain this phenomenon in great depth. One important aspect is that computer games seem to be more prevalent with rooky fire fighters, although we have also heard from a number of more senior players. Considering the general role of play as a preparation for later serious action, one might assume that computer games are one such way of experiencing and becoming acquainted with the unfamiliar and surely frightening prospect of a major fire fighting intervention. Another motivation probably is that in a computer simulation, the player can assume different roles from the one that he or she currently assumes during interventions, in particular roles higher up in the chain of command that might be on the career path later on.

Unsurprisingly, computer simulations have also been used by many emergency response organisations for training purposes. In the case of the Paris Fire Brigade this is not really the case. Only simple computer-based configurable visual representations of intervention scenarios have been used to prompt and train decision making by incident commanders. In any case, as was explained above, there is an important difference between computer simulations for professional training and as a leisure activity.

Based on our observations of the use of computer games, we decided to also create a computer-based multiplayer first-person fire fighting simulation. The photo in the middle of Figure  shows two fire fighters from the Paris Fire Brigade while playing this simulation. One of the key benefits of this approach is that the visual and acoustical interaction with information technology such as wearable computing equipment can be simulated in a comprehensive and accurate way. This is an advantage relative to the board game simulations discussed previously. With respect to training exercises the simulation of information technology is also easier in many respects. But there are of course more or less the same limitations for haptical and ergonomic aspects as for the board game. An interesting relative downside of the computer simulation compared to the board game is that the simulation is in fact richer and more explicit. In the board game much is left to the imagination and the players typically fill in what is missing based on their shared professional expertise. In the case of the computer simulation more aspects of the intervention are represented. While this brings the potential of a richer interaction it also brings the risk of limitations in the representation and artificial effects that might disengage or annoy the players. As a simple example, we learned that we had to enable our game character to move in a crouched position as this is standard practice under low visibility and our players did not accept to have to move in an upright posture. Besides general usability, another challenge with computer simulations, especially if their use is voluntary and not ordered as part of professional training, is that they must be sufficiently engaging and indeed fun to play. Luckily this does not necessarily mean that they have to be of the same quality as current game titles. As with the board game, many aspects of the simulation can be left for the players' imagination to fill in. But this does not mean that the aspects that are represented can be chosen lightly. Which aspects of an intervention have to be represented in the simulation and now has to be determined carefully based on the questions under investigation.

As a consequence, while the quantity and quality of design relevant feedback from computer simulations can be very high, the important caveat is that the initial investment in setting up the simulation is typically very substantial. Additionally, the necessary adjustments for specific investigations may require expert skills and also considerable efforts. On the other hand, depending on a sufficiently flexible simulation, some types of modifications can be done very easily and can in fact be put in the hands of the end-users themselves.

In our vision of the use of computer simulations as a non-compulsory self-organised leisure activity within the user community, the main potential comes from the possibility to conduct a number of simulation runs that can be largely higher than would be possible for the other types of simulations discussed in this paper. This includes both a larger number of participants and a continuous stream of simulations, probably resulting in a more varied and representative set of results.

## 4 Conclusions

Based on a concrete discussion of challenges involving the design of wearable computing technologies for the application domain of emergency response, we have framed a specific design objective as supporting the systemic innovation during the transition of the socio-technical system composed of technology, users and organisation towards a fitting and well-working new status quo.

We have illustrated a number of the concrete design activities that are part of the approach taken in the wearIT@work project to address this design objective. The discussion of these activities has shown their relative suitability to inform design and to support systemic innovation, with particular consideration for the specific conditions of an emergency response organisation and its members.

In terms of systemic innovation, two of the techniques – the board game and computer simulations – have a playful character in the sense that they facilitate exploring and reflecting on alternative concepts and behaviour. Especially the computer simulations seem to have the potential to drive a sustainable and continued process of systemic innovation.

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# Giving Access to Complex Content and Supporting Collaboration by Wearable Computing in Aircraft Maintenance

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**Abstract**

In the industrial maintenance sector the organization of productive plants requires work teams that are geographically dispersed. In order to improve productivity goals these groups are expected to pool their knowledge in order to quickly solve problems. New ways of improving operators tasks are needed in order to complement the activity of experts and the basic assumption is that wearable mobile computing can empower professionals to higher levels of productivity by providing more seamless and effective forms of access to knowledge at the point of work, collaboration and communication.

Within this context, one of the key application scenarios considered by the WearIT@Work project focuses, under the joint supervision of EADS (European Aeronautic Defence and Space Company) and GIUNTI Labs S.r.l., on the support of maintenance activities in the aeronautic industry.

This paper offers an analysis of some typical maintenance scenarios, which have been used as the starting point for the specification, design and realisation of an innovative wearable solution suitable to fulfil the main requirements identified by the application of a fully user-centred development approach. Main features currently offered by the solution are presented and discussed as well.

**Keywords**

User Centred Design, wearable computing, industrial maintenance, information management, collaboration.

## 1 Introduction

In the industrial maintenance sector the organization of productive plants requires work teams that are geographically dispersed. In order to improve productivity goals these groups are expected to pool their knowledge in order to quickly solve problems. New ways of improving operators tasks are needed in order to complement the activity of experts.

Within this context, one of the key application scenarios considered by the WearIT@Work project focuses, under the joint supervision of EADS (European Aeronautic Defence and Space Company) and GIUNTI Labs S.r.l., on the support of maintenance activities in the aeronautic industry. Maintenance effectiveness is one of the most scrutinized areas of airline operations.

The aeronautic industry takes maintenance aspects into account from the very beginning of the aircraft design in order to make maintenance tasks easier and faster. Through some scenarios, based on a real case studies at both Airbus and EADS facilities in France, the aim has been to demonstrate how wearable technologies can improve operators job and maintenance competitiveness by:

- 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

# 2 Background on the Maintenance Scenarios

The selected case study related to aeronautic maintenance is articulated through three specific scenarios, corresponding to some typical maintenance situations: removal and installation of equipment on the aircraft, inspection and trouble-shooting. These scenarios are described in more detail in the following sections and represent the background from which the activities of analysis, design and implementation of a suitable wearable application for maintenance support began.

## 2.1 Removal and Installation Scenario

In the aeronautics industry each aircraft must be regularly maintained for security, reliability, and performance aspects. In this scenario, the aircraft is at the maintenance centre for the replacement of large equipment, for instance the engine pylon (i.e. the part of an aircraft that supports the engine and related electrical wiring, hydraulic and fuel lines). This task requires a team of operators and a considerable toolset.

Before performing their job, operators get a “job card”. The “job card” is a paper folder describing the procedure of the maintenance task. First, the operators gather the information concerning the work situation (aircraft type, equipment to replace, tools and consumable to use, duration of the task, final tests, etc.). Before going on the aircraft, they need to read the procedure to well understand the different operations required. In many cases they visualise pictures included in the job card to know the exact location of the equipment on board.

Then, operators get the consumables and tools from the shop floor. If the tools are not standardized, the operators need to read the user manual. Moreover, if consumables listed in the procedure are not available, operators must find information on alternative ones. This kind of information can be found in the maintenance manual.

On the aircraft, operators prepare their task by securing the environment (de-energize or depressurize aircraft, put warning notices in the cockpit, tag circuit breakers, put access platform, etc.). The operators have to know the aircraft configuration and, for that, they need to share information with other nomadic workers already working on the aircraft.

Once at the location, the operators open the access (doors, panels, etc) to reach the equipment. Before removing it, they need to read the procedure to know exactly which functional and structural links they have to disconnect (for example: the wirings to unplugs, the headed nuts to unscrew, etc.). In the case of the pylon replacement, several operators are required on the access platform and on the ground. To disconnect the pylon and to move it down from the wing they need to communicate. To replace the pylon, several measurements have to be performed with specific tools and documents (calculator, torque values, etc.). At last, when the new equipment is on the aircraft, operators must complete different functional tests, which are described in the procedure.

During the task, they need to report on a specific sheet all actions done on the aircraft and all data collected (torque couple, oil level, test results, etc.). At the end of the job and depending on their expertise level, each operator stamps the specific sheet to finalise the task or ask a maintenance expert to check and validate the job.

## 2.2 Inspection Scenario

In the aeronautical maintenance domain improvisation has no place. All information about each inspection is defined, and the operator has to follow systematically the procedure. This scenario is based on a scheduled inspection. Like in other scenarios, the aircraft is in a maintenance centre. Also in this case the operator uses a "job card" where he can find all information concerning the inspection he has to perform. He gathers the information concerning the work situation (aircraft type, name of the inspection procedure, etc.). Before going on the aircraft, he has to read the procedure to fully understand the different steps of his maintenance task. This procedure is divided into few sections which allow him to be informed of the preparation of inspection phase, the instrument calibration he must perform, the inspection procedure phase and general important information such as the component or area to be inspected, the description of the possible damage, the related documents he might use, the acceptance criteria, etc.

Once the operator is aware of these information, he gets the equipment and materials specified to perform this task; they are all listed in the inspection procedure. It is important to notice that the operator cannot take other materials than those specified. Moreover, if they are not available, the operator must find information in the maintenance manual on alternative ones if they exist.

Then he applies the preparation of inspection procedure section. For that he has to be sure that the area or component to be inspected is accessible (by removing panels, fitting corner, etc), that the surface to be inspected is clean and smooth, and must check the inspection area for any visible damage or discontinuities. After that, the operator must calibrate the instrument by following the different steps proposed in the instrument calibration section of the inspection procedure.

Then, he can start the inspection procedure. The operator will follow it step by step. In most cases, the operator must repeat the inspection two times to confirm the results he obtained. The acceptance criteria are given in the inspection procedure. The operator has to compare his measurements with them. If measurements are out of the criteria bracket the inspected component must be changed, and the aircraft will be able to take off only after this change and with an expert agreement.

During this inspection task, the operator needs to report on a specific sheet all actions done on the aircraft and all data collected (inspection results, etc.). At the end of the job and depending on his expertise level, the operator stamps the specific sheet to finalise the task or ask a maintenance expert to check and validate the job.

## 2.3 Trouble-shooting Scenario

A fault has been identified by the warning system on board. On the ground the operator has to isolate and repair the fault. The trouble-shooting task consists in searching the cause and nature of a fault. Trouble shooting mainly concerns systems in the aircraft. From an information or anomaly written on the logbook by the pilot, the task consists in localising the system failed.

From the faults list coming from the "Post flight report" (a warning system in the cockpit) and after a discussion with the pilot who reports the problem on the logbook, the operator performs the trouble-shooting procedure according to the fault symptoms he wants to resolve. The fault symptoms corresponding to the fault isolation procedures are provided under electronic link. The fault isolation procedure, which is again closed up by reporting the task achieved in the logbook, contains:

(a) Possible causes: this lists all the suspect items which are replaced or checked during the procedure

(b) Job set up information: the operator has a list of any tools, equipment and procedures required to be carried out before commencing the fault isolation

(c) Fault confirmation: the operator confirms or not the fault by performing the test required

(d) Fault isolation: the operator realises the appropriate actions to isolate and correct the related fault symptom

# 3 Analysis of Requirements

The processes of inspection, removal and installation and troubleshooting are all information intensive and usually require careful and in-depth training. In order to perform them the maintenance operators need to plan all the information/documentation needed in advance, together with all the tools and consumables they need to use. In addition, all these processes involve communication with experts in doubtful situations or with other team members. In all the cases the maintenance operators need to perform proper job reporting regarding all actions performed.

A basic assumption is that in a maintenance centre the activities are performed by maintenance teams, i.e. physically distributed groups of users. This implies the availability of functionalities for supporting collaborative work. From a different perspective, the information needed by the operator might be stored in different places (maintenance centre server, on-board server, etc.). Therefore, functionalities for the management of distributed data repository should be foreseen. From a careful analysis of the available scenarios some main requirements have been identified, which are outlined in the following sections.

## 3.1 Communication and Collaboration

Using the wearable the maintenance operator shall be able to get in touch with other operators when needed. This in order to ask for help in case of necessity, request either advise from a maintenance expert or the validation of a report to finalize the task. Moreover, in all the maintenance scenarios the importance of collaborative activities is highlighted. Collaboration and communication is foreseen between on-site operator and remote expert, amongst operators working at the same task and between maintenance operator and the aircraft pilot. Usually there is no network connection on the aircraft. Therefore suitable wireless technologies must be made available in order to guarantee the communication between operators and between the operator and the main data server. Also the communication between the wearable and other devices (measurements devices, probes, etc.) should be guaranteed. Several technologies can be investigated (WiFi, Bluetooth, GPRS, etc.). More generally, the whole workspace shall be covered by a wireless network.

## 3.2 Data and Information Access

Most of the information the operator needs is in the form of multimedia documentation (job cards, inspection procedures, maintenance manuals, fault isolation procedures, reports, etc.). These information resources will in the form of digital contents containing text, images, videos, schemas, diagrams, etc. The system shall be able to provide the following functionalities:

- Advanced digital repository management
- Advanced content management
- Content search

- Content personalization and customization
- Content rendering and visualization
- Management of different kinds of media.

To preserve data and information consistency the wearable should be able to synchronize with several information management servers. This allows keeping the consistency between information available to the operator through the wearable system and the actual status of the aircraft (configuration, maintenance history, current manuals, current maintenance tasks, etc.).

### 3.3 Multimodal Interaction

In order to allow the operators to work hands free, besides more traditional interaction modalities (keyboard, pen, finger mouse, etc.) at least voice-based interaction shall be provided (speech analysis and synthesis). The availability of a kind of "virtual keyboard" would be requested. The interaction with the virtual keyboard could be managed through a micro-camera system that ascertains user's fingers position. Gesture-based interaction should be investigated as well as a possible solution.

### 3.4 Context Awareness

The wearable platform should be equipped with sensors suitable for gathering information about the working environment (environmental conditions, location, aircraft status, equipment status). Two other important components of the contextual information that should be considered are the user profile and the user location/position. A suitable hardware infrastructure for locating the operators with high accuracy (< 2m) would be needed, as well as proper client/server software. Basic functionalities that shall be supported are: position of users in the maintenance centre, position of relevant items in the maintenance centre, maintenance centre navigation.

### 3.5 Records and Indexing

The maintenance operator is requested to fill in a report during his activity. The report contains information about actions performed, data collected, inspection/fault isolation results. The report will be designed and implemented as a digital content ideally containing several media (text, pictures, etc.). Besides normal functionalities for managing digital contents, the following shall be supported: advanced reporting and annotation, visualization and management of forms and questionnaires, voice/virtual keyboard-based insertion of a new note.

### 3.6 Wearable Hardware Platform

Should be highly portable and available whenever and wherever the user needs to work. More specifically, the platform is expected to be unobtrusive, in order to allow situations capturing/knowledge retrieval without obtrusions from the technology, and adaptable to both the working context and the operator's personal preferences/needs evolving skills and knowledge. To support the communication amongst users of the application noise-robust headset and microphone need to be provided, as well as a micro-camera for video-based communication. At least two different kinds of displays, a "see-through" head mounted display and a flat screen to put in a pocket of what has been identified as the "Maintenance Vest", have to be available.

## 4 Current Status of Implementation

The current prototype of the maintenance solution can be seen as an incremental development of the previous demonstrators realised within the project, with specific focus on a tighter integration of the different hardware and software components already identified as fundamental to deploy a robust and stable solution that can be efficiently and effectively adopted by end users.

Having as a reference the previously discussed scenarios, the basic features offered by the proposed solution can be summarised in terms of support to a typical maintenance operation. The user is assigned to a specific task, takes the wearable equipment and switches it on. A list of pre-assigned job cards is presented on the wearable HMD worn by the operator. The user selects one card and moves in the working area where the aircraft to be maintained can be found.

The operator opens the job card and accesses the multimedia information related to the specific intervention he has to deal with. This information consists of structured multimedia procedures including text, images, electrical/mechanical schemas, warnings (see Figure 1)

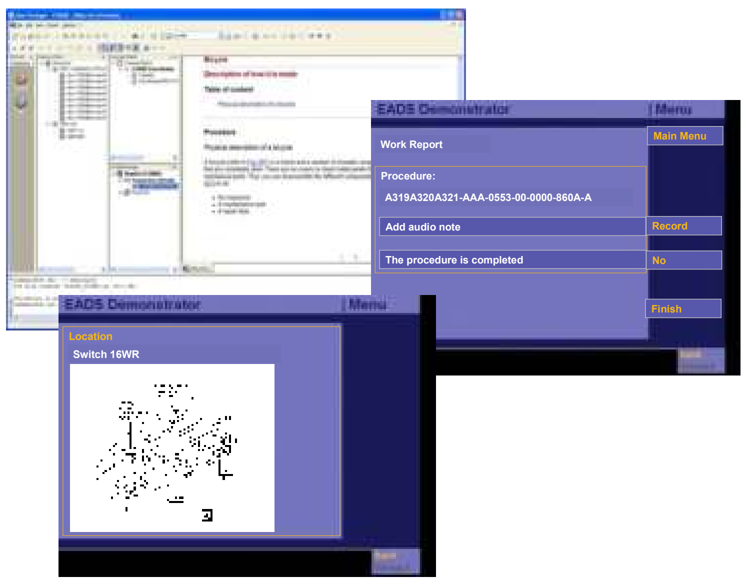


Figure 1: Some screenshots of the maintenance solution.

Once the task-relevant information is displayed, the operator starts the maintenance procedure by using the available documentation and following the provided instructions At a certain point an unexpected damage is discovered by the operator, who has doubts about how to proceed. Therefore a voice call to a remote expert (or tutor) is issued in order to get more information about the part under investigation.

The remote expert analyses the image coming from the working area and decides that more details are needed. Therefore, the on-site operator is requested to take a picture of the damaged part and send it to the remote expert. After a quick visual analysis the specialist understands the kind of support needed by the operator in order to complete the task. The image is annotated, some relevant documentation selected and all this information sent to the operator.

The site operator goes on with the procedure, also using the received additional information, and then decides to take a note about the performed procedure step. A suitable interface is presented and filled in with a short text, which is then stored in a repository after a proper linking with the specific procedure/step is achieved. This note is now part of the company knowledge base and represents a piece of intrinsically informal knowledge, which has been formalised and can be searched for, retrieved and presented to another operator when needed. Since the procedure is traceable, a report including all the performed steps and an indication of their successful completion is automatically generate. The operator can then check the report and validate it if correct.

The current version of the demonstrator offers the following functionalities:

- Login and authentication of the user, by means of RFID technology.
- Access to task-relevant multimedia information. Procedures are created and managed as S1000D files, thus following a widely accepted standard specification for technical documentation.
- Recording of voice-based annotations by the operator and linking of the annotations to the corresponding step in the procedure (implicit knowledge management).
- VoIP-based and text-based (chat) communication with a remote expert.
- Expertise projection by means of image capturing and transmission, remote exchange of information.
- Reporting and task/procedure validation

The software used to implement the maintenance application interface is based on the Wearable User Interface Toolkit (WUI-Toolkit) developed within the project context. The toolkit already supports in its default configuration the ability to develop user interfaces (UIs) that can present information using the selected displaying techniques. Therefore, implement the UI needed to fulfil the tasks was reduced to specify an abstract model that corresponds to the type of information being presented to the user. This has been instantiated for S1000D documents, in order for the application to be able to retrieve a generic procedure from a repository and properly visualise it on a wearable device by means of a chain of suitable transformations.

An advanced speaker-independent speech recognizer has been used to recognize spoken commands of the user. A spoken command can be either the name of a certain menu item or one of three predefined commands to control the cursor. By stating the name of a menu item the navigation is directly triggered, i.e. the cursor is moved to the menu item and then directly selected. In case of using the predefined commands users have to speak a corresponding sequence of commands. No visual focus is needed to post spoken navigation commands. More advanced speech-based features are currently under integration, which will allow for a mouse-like interaction using simple phonemes.

All hardware components belonging to the maintenance solution - including the OQO device selected as central computation and control unit - are integrated in an advanced and innovative "maintenance vest" (see Figure 2). Main features of this improved and reconfigurable clothing item include: removable pockets and OQO tubular arms (horizontal and vertical position), side regulation to improve wearability, mesh zones to allow for a good transpiration, X-structure, for body close-fitting and better weight carrying.

Figure 2: Enhanced maintenance vest (courtesy Grado Zero)

Two different interaction devices are integrated in the solution:

- *Gesture Device*: a data glove equipped with motion sensors. Users control a cursor with different gestures performed by the hand that is wearing the glove. Gestures can be performed without maintaining visual focus on a screen.
- *Microphone*: a commercial device has been used to support speech-based interaction. An innovative bone microphone is currently under testing, which should allow for better performances and an increased voice-independence.

As output devices a *MicroOptical SV-6 HMD* and a headset (headphones) are available. Additionally, the option of integrating a new monocular device developed by Zeiss is under investigation.

RFIDs are integrated in the application for the purpose of identifying both the operator (during the login phase) and relevant items in the working area (e.g. the specific model of a seat).

Bluetooth is used for the communication between the data glove and the wearable device, while a WiFi network is adopted for supporting the access with a remote procedure repository and the communication/exchange of information between on-site operator and remote expert.

## 5 Conclusions

Thanks to the WearIT@Work project and its previously described achievements, in the future working scenario fostered by EADS and the end users, the maintenance operators will be equipped with a maintenance vest, with integrated wearable technologies in it, both early in the training phase and during the daily activities. The wearable computer will be equipped with suitable input devices, which register measurements taken during the maintenance procedures and allows the user interacting with the system, and displays. The expected main benefits of using the proposed maintenance solution, the related input/output devices and an advanced content management and presentation system are:

- 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.

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# Does Wearable Computing Really Empower the Mobile Worker – Findings from Ethnographic studies

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**Abstract**: This paper surveys the impacts, both positive and negative, of technological development in the workplace using Dr. Neil Postman's doctrine of media ecology as a means of exploring whether wearable computing can empower the mobile worker. This is based on the wearIT@work project's four year living lab effort to develop, deploy and evaluate a wearable support system in four different industrial working scenarios: production, maintenance, emergency response, and healthcare. The ideas presented here rest on the often overlooked understanding that technological development and design must take into consideration and include the social aspects and implications of the said technology. It is important to understand the positive and the negative aspects of technology from a social perspective in order to emphasize the good and moderate the negative impacts.

**Keywords**

Wearable computing, ethnography, user centred design, media ecology, living labs

## 1 Introduction

The success of wearable computing introduction, and in particular user acceptance and adoption, is dependent on a set of human, social and organizational factors. A technological and organizational system design, which explicitly addresses these factors can enhance implementation success rate. Thus the main research question is: what are the impacts of the introduction of wearable computing on the social dimensions of the workplace?

Neil Postman stated that culture always pays a price for technology (Postman, 1992; 1998). All technological change is a trade-off – for every advantage a new technology offers, there is always a corresponding disadvantage. The disadvantage may exceed the advantage, or the advantage may be worth the cost. This paradigm is often overlooked in a world in which technological development has become synonymous with progress, thereby creating a certain level of ambivalence to the effects of technology on humans as social beings. One small example of this is the ubiquitous use of cell phones. On one hand, always having a cell phone on hand creates an easily recognizable and appreciated level of convenience unimaginable prior to their development. On the other hand, little credence is given on the individual level to the cell phone's disruption to our social interactions, leisure time, intimacy of our human-human contact, cultural events (when someone doesn't turn off their phone), not to mention the implications of prolonged cell phone usage on our health.

In his book MegaTrends, John Nesbitt claims that while technology has accelerated rapidly, social change has not kept the pace, and as a result there is an increasing gap between technological and social change, which is manifested for example in a search for meaning, a desire for deeper relationships and a sense of community and a tendency towards spirituality. One of the key success factors of a technology and at the same time the successes of an organization, is in restoring the balance of Hi-tech and Hi-Touch, by designing the technology and the work environment in a way that meet the human needs of personal growth and social relations.

Wearable computers bring a new level of digitization into every day life. Unlike a laptop or a PDA, a wearable computer follows us around, and merges into our style of living and everyday interactions. Thus, it demands a paradigm shift in the perspectives on reality and human interactions. Wearable computers introduce new concepts of “mediated reality” and “augmented reality”. Augmented reality is augmenting the real world with additional information and by doing so enhancing the users' experience of that reality. Mediated reality refers to encapsulating the users’ senses by processing information from the outside world and filtering it for the user. One of the main challenges of wearIT@work has been to design the new reality of the users in a way that will address both the Hi-Tech and Hi-Touch needs of the users, in a combined and seamless way.

## 2 User feedback in wearIT@work

Through ethnographic research and questionnaires, social data was collected from end-users testing the wearable prototypes developed throughout the wearIT@work project. These prototypes were developed for four industrial scenarios, each represented by a different industrial partner: Maintenance (Airbus maintenance facilities), Production (Skoda production plant), Healthcare (Gespag Hospital), Emergency Response (Paris Fire Brigade).

While some technical difficulties with the prototypes made collecting social data difficult in many instances, end-user response to the idea of using wearable computers in the workplace was generally favorable. Wearable systems were seen as reducing stress and frustration in the workplace, factors that contribute to burnout. They were also seen as increasing communication, building trust and camaraderie among workers.

At Skoda, workers felt that a wearable computing system would make their work on the production line faster and more efficient, prevent mistakes, and increase communication and work flow with co-workers. Outside the benefits to their workflow, workers were enthusiastic about the possibilities that the wearable system opened up for electronic social interactions among co-workers through a chat system integrated into the prototype.

The issue of frustration in the workplace arose while observing and interviewing medical at the surgical ward in Gespag hospital in regard to the computerized system they currently use. This system is not portable and does not include all the necessary data (some is still written in paper files). In addition, the system is slow, not selective with the information it provides and the user must navigate through a number of windows in order to find the relevant information. As such, doctors and nurses expressed enthusiasm that a wearable computer system be operational at the hospital in the future. They viewed such a system as having the potential to reduce the time it takes to complete tasks, thus reducing workplace frustration and stress. The fact that wearable computers help keep hands sterile during procedures was noted as a significant benefit. Patients at the hospital also showed positive interest in the wearable system stating that seeing results on the screen and having them explained to them in real-time increased their trust in their doctors and in the overall care they were receiving.

## 3 Considering social aspects in design

A set of social factors which should be addressed by the players involved in the system design in order to maximize desired system outcomes. This group includes the designers of the device and software, the designers of the extended socio-technical system e.g. planners of work processes, the experts leading the implementation process, and, of course, the end users.

The set social factors includes three general types of factors:

*Human:* related to the individual user.

*Social:* related to the relationships between two individuals

*Organizational:* related to the relationships of the individual with the organization in which he/she operates.

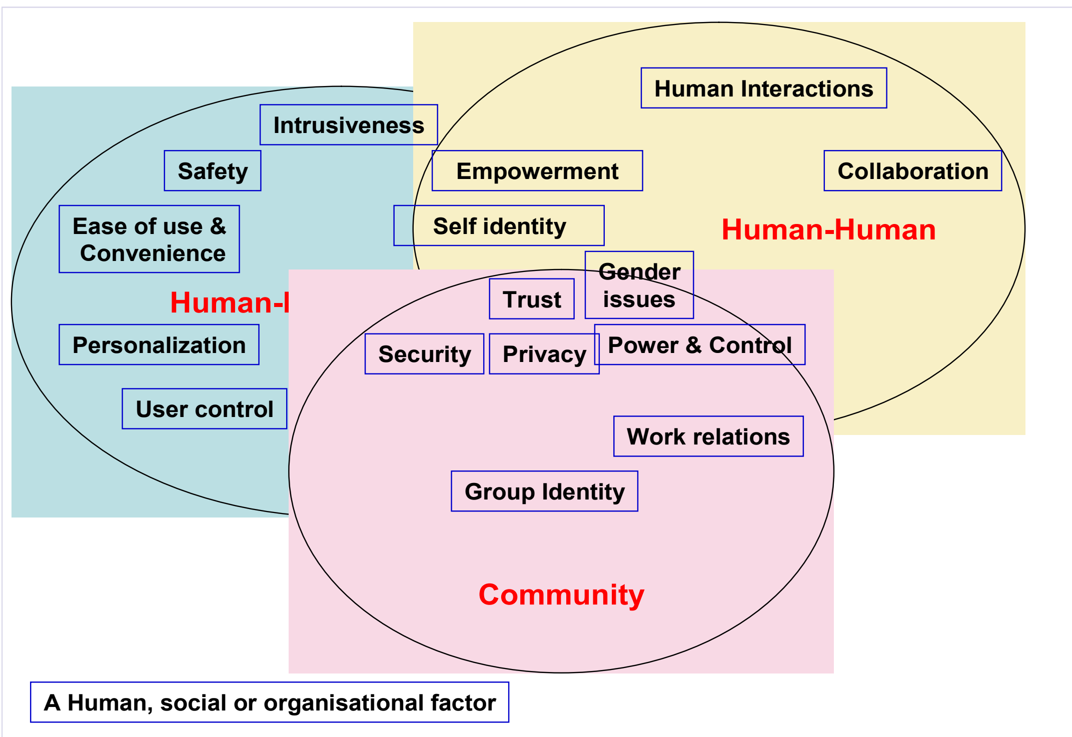


**Figure 1: Human, social and organizational factors**

In an ideal world, all the social-human factors would be fully addressed and comprehensive solutions would be designed. However, there are constraints: designer resources, time to market and system cost. Because these factors are interrelated, altering one of them may affect another. Moreover, some factors are conflicting, i.e. enhancing the system performance related to one factor might decrease the performance related to another factor.

For instance, a wearable computer equipped with GPS can be of great help if an individual is injured and needs help, but it can also be the perfect tool for an employer to find out if the workers are spending too much time in the donut shop! The answer lies on a complex balance between comfort, security and ownership of personal data (Viseu).

Thus, sometimes the problem can become part of the solution. For example, if the wearer controls information contained in it, then he/she can decide when, where and why to disclose it. In this case, the computer initially thought to risk user privacy can become a tool to protect it.

## 4 Conclusion

It is necessary to make design decisions based on prioritization and balancing of conflicting factors in order to create a holistic, socio-technical wearable system. If designed with the user and his/her social needs in mind, wearable computing has the potential and capability to bring significant benefit to the workplace and to society at large. By placing the emphasis on empowering the mobile worker rather than on increasing the bottom line, a confluence can be found between hard business benefits, such as lower time to market and increased productivity, and the softer social benefits, such as increased employee satisfaction, quality of life, and loyalty, and improved corporate image – all of which ultimately spur business growth.

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# Exploiting Research Results in Practice

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**Abstract**

With the wearIT@work project the European Commission and 42 partners from 16 countries invested into a new technology empowering mobile workers. The first 42 months of this project are over and industrial demonstrators, evaluations and results and an exploitation strategy are available. Beside the four application domains of maintenance, production, healthcare and emergency response further domains like cultural heritage, a rural living lab for the prevention of environmental disasters and eInclusion are first extensions to new application domains. In this paper based on the results of the third development cycle of the project the general outline of the exploitation strategy is presented as a good practice example.

**Keywords**

Wearable computing, applications, exploitation of research results

## 1 Introduction

wearIT@work [1] was chosen by the European Commission as an Integrated Project to investigate "Wearable Computing" as a technology dealing with computer systems worn as unobtrusively as clothing. From 16 countries the project has 42 partners, among them EADS, HP, Microsoft, SAP, Siemens, Skoda, Thales and Zeiss. The consortium consists of end-user organisations with strong impact on the respective market like automotive and aeronautics. Furthermore strong partners are in the consortium to ensure that solutions found will benefit as far as standardisation is addressed. SMEs are in the consortium as consultants and application and system integrators as it is expected that based on solutions found new business for this kind of companies is created. 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 previous publications the background of the project [2], the research methodology [3] and earlier results [4, 5, 6, 7] were described. The project started June 2004 and has an overall duration of five years where the last 6 months are especially dedicated to exploitation.

The project follows a cyclic research approach in Living Labs as described in [6]. This ensures that solutions found are evaluated in a rapid manner. To ensure that the project results can be used beyond the project team a Business Model working group was established. To initiate the discussion the working group took a tutorial on business models [8]. In two Stakeholder Workshops with more than 100 participants each time the team gained experiences concerning the concrete implementation. The working group discussed with different partners on their marketing strategy to better understand restrictions coming e.g. from globally acting companies as well as SME.

## 2 Objectives

The objective of this paper is to explain for the innovative technology of wearable computing the exploitation strategy and technology implementation plan and the overall business model and business models for the four pilots as well as the three take-up projects after the 3rd year of the project. All seven wearIT@work solutions are based on the Open Wearable Computing Platform (OWCP) and the Open Wearable Computing Framework (OWCF) as described in [6]. The basis of exploitation in wearIT@work are the specific value chain and simple, but we believe important, rules for implementing the wearIT@work corporate model for doing business. The adoption of those rules creates a learning cycle that let each single initiative take advantage of benefits coming from the partnership and, on the other hand, contributes to enhance the value of the organization.

## 3 Methodology

Components and technologies adopted in the different pilots are many and heterogeneous. A common business model among pilots due to the complexity behind the work done so far is impossible. However, creating business by combining and integrating components and services based on the software framework and the platform was already shown by the take-up projects which are very close to the market and represent test beds for many components and technologies of wearIT@work. Furthermore there is no need to deal too much with the IPR issues as take-up partners are full members of the project consortium. Thus we can focus on solving the technical problems enhanced and gain experience in know-how and technology transfer during the last phase of the project.

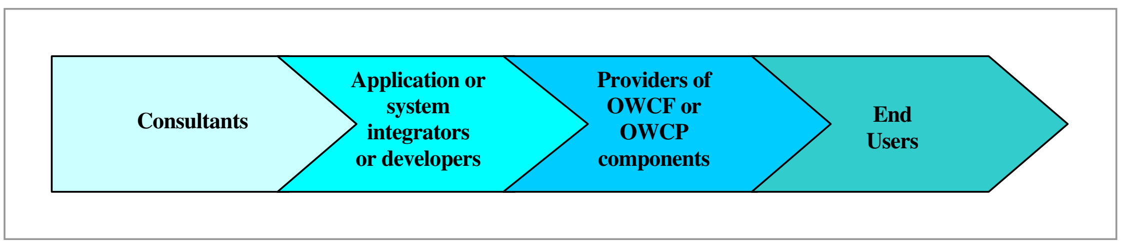


Figure 1 - Value chain of wearIT@work project

As the wearIT@work solutions are not yet final, such is the exploitation plan; here the actual approach: All 42 wearIT@work partners benefit from the findings of the project and, at the same time create value providing competence, services, methodologies and technologies. The partners are clustered to the four groups indicated in Fig. 1:

**Consultants** identify the potential benefit out of a wearable computing approach. They also cover all organizational aspects and derive a concrete wearable computing solution or at least a pilot for evaluation by end users. Consultants define the job for application developers and system integrators as far as these are not able to define it independently. In so far consultants prepare a market for application developers and systems integrators. They can also consult other consultants based on their wearIT@work experience and knowledge. Furthermore, they might also consult application developers and system integrators from outside the wearIT@work project or within their networks.

**Application or systems integrators/developers** can start based on a concrete specification given by a customer (end user) or as subcontractor of a consultant in case a turn-key solution is required. Application developers need based on the specific requirements the components of the software framework. Application developers or systems integrators involve the partners of the OWCF and/or OWCP.

**Providers of OWCF/OWCP components** create business by consulting their clients getting another access to the value chain. They involve application developers, systems integrators and other component providers based on our implementation rules (see next section). They deliver their competence in a project or product approach depending on their company's rules. Providers can also consult application or system integrators/developers to use the OWCF/OWCP.

Finally **end-users** (our pilots) create business as they at the end or on top the value chain ask for improvements of their core business and address committed to our implementation rules the wearIT@work partners for the solution.

# 4 Business Rules

The goal of the rules as indicated in the following table is to create a common framework in which partners operate facilitating the creation of business.

| **No** | **Business rules** |
|---|---|
| **1** | All partners are committed to invest marketing efforts in disseminating the results of wearIT@work. |
| **2** | Dissemination of results is focused on creating a business support group (BSG) which generates leads for training, consulting and solution providing services. This is a subgroup of the OWCG (www.owcg.org) – just dedicated to business development; the initial members are the consultants within the wearIT@work team. All partners can benefit from this important activity. Creation of a brand identity is aimed at. |
| **3** | All partners give other relevant partners "first right of refusal" when an opportunity emerges for proposing a service: The partners ask one another to join a business opportunity before one gives an application integration or system integration to another contractor not member of the wearIT@work business support group (BSG). This should stimulate cross-fertilization of technologies and reinforce collaboration among partners. |
| **4** | Generic lessons learnt from successes and failures of marketing and sales efforts as well as from training, consulting and solution providing projects are shared with the other partners for effective knowledge sharing. This is organized by the BSG avoiding repeated mistakes and strengthens success stories. This activity is managed by the OWCG which will stay beyond the wearIT@work project. |
| **5** | The consortium partners committed to stay in touch as a learning community and contribute to the OWCG website and to IFAWC (www.ifawc.org) as the two major marketing tools beyond the end of the project. |
| **6** | One partner volunteers and then be elected to lead the OWCG learning community beyond the end of the wearIT@work EU funded project. First right of refusal for this opportunity is given to the coordinator of the wearIT@work consortium. |
| **7** | Each partner pays a minimum annual membership fee determined before the end of the project to the wearIT@work learning community. Marketing efforts are made to attract new members to this community and to recruit sponsors for additional fund raising for more activities such as a newsletter, etc. |
| **8** | In the IFAWC annual meetings there is a business meeting serving as a management tool of the OWCG. |

The developments of the project were all made public using the homepage of the project. There a Technology Repository was set up listing all hardware and software components and solutions developed so far together with an indication of the technology readiness at the beginning of the project and at its actual state. The above value chain of exploitation and the business rules might be applied when initiating a wearable computing project by any of the project partners.

## 5 Business Benefits

There are quite some examples of results ready for immediate exploitation. The *LINKVest* is a vest based on a design that was originally developed for the aircraft maintenance showcase (fig. 2). It integrates wearable technologies as a container and is an example of a product ready to be marketed. It was developed by the project partner Grado Zero Espace as shown in figure 3 for different application domains like production, logistics and service. It is a solution ready for any application where based on RFID tags context relevant information can be accessed using a wireless IT infrastructure.

Figure 2: Vest and interaction glove for aircraft maintenance

The evaluations with end-users in the aircraft maintenance domain with its demand on structured information and extensive documentation we found that 50% of the time workers spent to catch up print outs and document on paper tasks performed. However, this approach is not only applicable for the aircraft maintenance domain but also for other application areas like maintaining machines, trains, chemical or power plants as in all these domains paper based work can be replaced by wearable computing solutions. The figures might be different in other domains; however, there is an approach to increase productivity by replacing paper bound processes by wearable technology using process analysis as a basis for the return on investment calculation. The business benefit of the technology can thus been easily shown.

As a result the new generation of optimized collaborative man-machine interfaces (glove with WUI toolkit of the OWCF), with body near context detection will already be marketed at this stage of the project. Further hardware and a first version of the software framework are available. For this purpose we developed based on the maturity level definition of the US DoD[1] for all components and solutions the achieved maturity levels and published this in the technology repository of the project homepage as mentioned above. This allows other parties to start a dialogue with the project partners for further development and exploitation.

By this public approach the project also addresses standardization issues and pushes developers of devices, components and systems to participate in the process.

Figure 3: *LINKVest* as a reconfigurable clothing device

## 6 Lessons Learnt

The basic idea to use an open and common ***software framework*** (OWCF) as middleware for the application development was the right approach, as the tools have significantly sped up the development and made the applications easily modifiable. Industrial partners in one pilot (healthcare) have even made the use of the Framework a condition to the integration of the application with their system.

Although the ***virtual reality simulation*** was only used on the emergency scenario we believe it to be a crucial instrument in the design and implementation.

Our evaluations have confirmed the significance of ***context*** for real life use of wearable systems however with variability of requirements. There are applications requiring detailed task tracking, others where the proximity between different protagonists is relevant or elaborate location and physiological sensing. Concerning indoor localisation we found that there is no unique approach so far and still research required. Some sort of ***speech input*** has been a common wish made by users in all pilots. However due to technical concerns and after some more detailed analysis it has not been implemented in all scenarios. Instead the tests so far have exposed the diversity of possible input modalities and the optimal modality has not yet been. ***Head mounted displays*** have met with acceptance in three pilots. However, conventional tablet PCs and stationary displays can nicely harmonize with wearable systems. There is still research

[1] TRL: Technology readiness levels (US Department of Defense) DOD Deskbook 5000.2-R

required to further test what type of information presentation is optimal for which application. In particular the interplay between display complexity and context, as way of reducing the communication bandwidth between the system and the user, is still not sufficiently understood. The ***form factors*** of modern micro PCs such as the OQO are acceptable for most applications and their robustness and standard interfaces are preferred by the users to nice, yet more exotic devices such as the QBIC. More problematic are ***battery life*** and ***heat production***.

## 7 Conclusions

The most significant result of the wearIT@work project so far is the diversity of wearable applications that it has exposed. Across such different fields as healthcare, production, maintenance, and emergency response we have demonstrated not just plausible application scenarios but also user acceptance and technological feasibility. There's strong indication that wearable technology has the long-term potential to change the out-of-office workplace just as much as personal computers changed the office environment.

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 that is planned to sustain long after the official end of the project in 2009. The value chain, the business support group and the business rules are designed to further strengthen the field but also give an idea how to bring new technology in a knowledge society in place by a learning cycle.

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[7] Lukowicz Paul, Timm-Giel Andreas, Lawo Michael, Herzog Otthein: WearIT@work: Towards Real-World Industrial Wearable Computing, *IEEE Pervasive Computing*, vol. 6, no. 4, 2007, pp. 8-13.

[8] A. Ostenwalder, Y. Pigneur, and C.L. Tucci: Clarifying Business Models: Origins, Present, and Future of the Concept. In Communications of AIS, Volume 16, Article 11.

**Acknowledgement**

This work has been partly funded by the European Commission through IST Project *wearIT@work: Empowering the Mobile Worker by wearable Computing (No. IP 004216-2004)*. The authors wish to acknowledge the European Commission for their support. We also wish to acknowledge our gratitude and appreciation to all the 42 wearIT@work project partners for their fruitful work and contribution during the development of various ideas and concepts presented in this paper.

# Presentations on CD

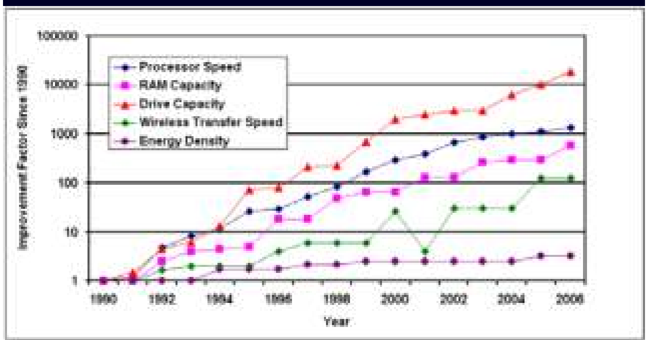
- **The Next Six Big Things in Mobility**
- **Results Overview on the Activity Recognition Problem in the Škoda Production Scenario**
- **Supporting Mobile Workers in Car Production by Wearable Computing – Applied Context Detection**
- **Wearable Computing in Healthcare – from an idea to a working system in daily business**
- **An Approach to Systemic Innovation of Information Technology for Emergency Response**
- **Giving Access to Complex Content and Supporting Collaboration by Wearable Computing in Aircraft Maintenance**
- **Does Wearable Computing Really Empower the Mobile Worker – Findings from Ethnographic studies**
- **Exploiting Research Results in Practice**

## The Next Six Big Things: Mobile Interfaces for Changing the World

Thad Starner
Associate Professor of Computing
School of Interactive Computing
Georgia Institute of Technology

## 15 Years of Daily Wearable Computing

## Progress of Laptop Technology




[Dvorak2007 based on Starner2002]

## #1: Mobile Phones as PC

- 2 billion mobile phones in use (versus 900 million PCs)
- Mobile phone taking over traditional desktop tasks
  - In Japan, more e-mail sent via phone than home PC
  - Television, radio, e-mail, spreadsheets, etc.
- Developing world: mobile phone may be the ONLY computer/communicator available
  - Liberia has 5km of phone line, but 4 mobile phone companies
  - Microfinance/banking
  - Citizen reporting

## #2: Digital Convergence on the Body

## "Crackberry" Effect

Rick Mercer Report, CBC

## Device Problems Can Be Solved; Users' Problems Just Beginning

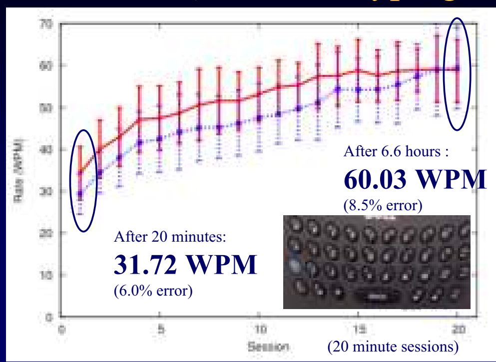
- Limited dexterity (e.g. "fat fingers")
- Limited vision (e.g. vibration while walking or riding)
- Split Attention
  - Computer interface often secondary
  - User may need full attention quickly

## On-the-go Interfaces

- Assume computer is secondary
- Access time 2 seconds or less
- Design for 4 second blocks of attention
- Use different modality than primary task (e.g. audio while driving)

## #3: Dominance of Typing

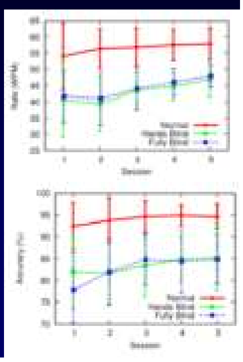
## Mini-QWERTY Typing




[CHI05]

## Revenge of the Crackberry Effect

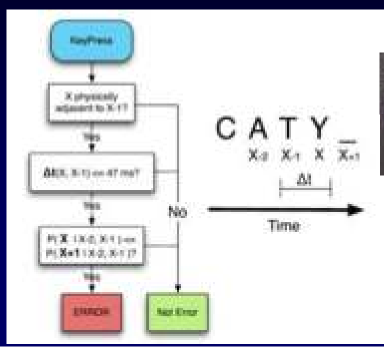
- If can't see keyboard: 45wpm and 14% per character error rate!
- Explains why such attention needed! Implications for
  - Walking
  - "Secret" typing in meetings
  - Driving

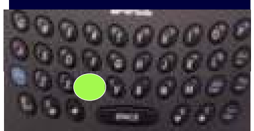


[ISWC05]

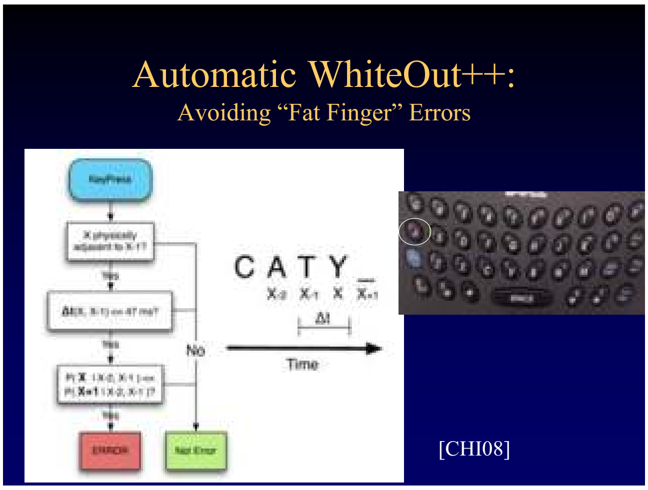
## Automatic WhiteOut++:

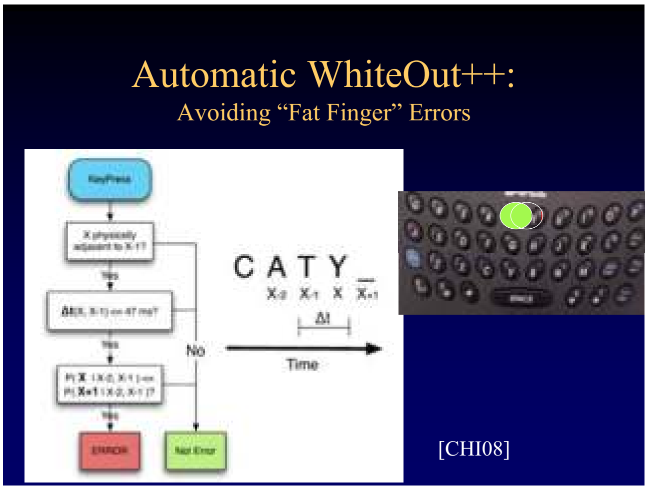
Avoiding "Fat Finger" Errors

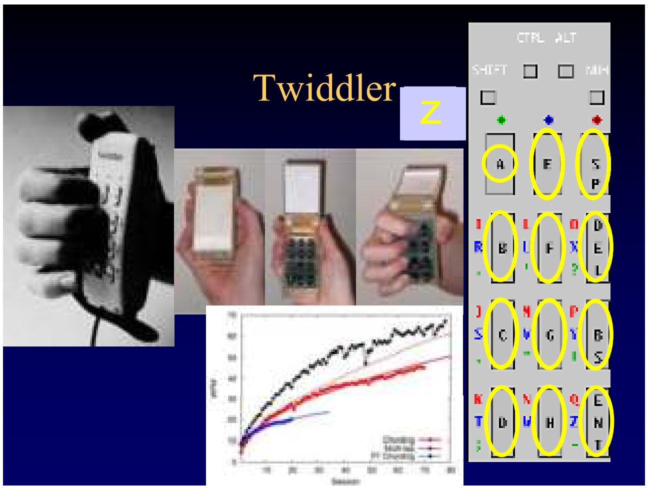


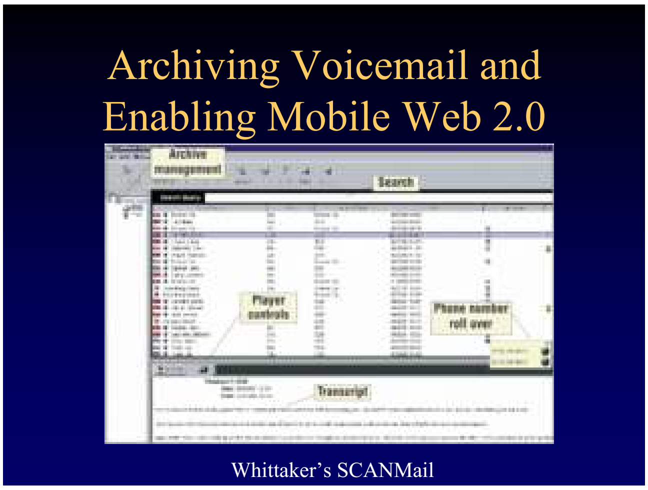
[CHI08]


Automatic WhiteOut++:
Avoiding "Fat Finger" Errors
KeyPress
Yes
No
ERROR
Not Error
C A T Y _
Time
[CHI08]


Automatic WhiteOut++:
Avoiding "Fat Finger" Errors
KeyPress
Yes
No
ERROR
Not Error
C A T Y _
Time
[CHI08]


Twiddler
Z
CTRL ALT

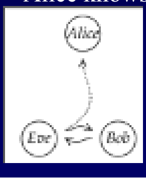

#4: Speech as Data and
Social Interfaces

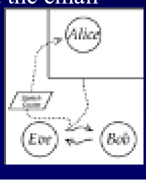

Archiving Voicemail and
Enabling Mobile Web 2.0
Archive management
Search
Player controls
Phone number roll over
Transcript
Whittaker's SCANMail


Dual Purpose Speech:
The Calendar Navigator Agent
Calendar display "follows" conversation
"Can we meet next week?"
"OK, David. We'll meet Tuesday at 1."
[UIST04;Mobile HCI05]

## Speech Courier

- Relay conversation to third party
- Eve: “Alice will email you the write-up for our new proposal”
  - Bob understands he will get an email
  - Alice knows to send the email




## #5: Mobile Gesture

## FreeDigiter:
When Buttons Are Too Big


## Mobile Dance Revolution

## #6: Augmented Reality

## Context Recognition in the WearIt@Work Project

**Paul Lukowicz**
**University of Passau**
**Germany**

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ETH Zürich


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Uni Pasau

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- David Bannach, University of Passau

## Overview

1. First Generation
   - heavily augmented environment in training applications
2. Generation 1.5
   - simulated repair task with wearable sensors
3. Second Generation
   - Initial spotting of activities in real world production scenario (offline)
4. Third Generation
   - real time reliable spotting of activities in production scenario
5. The Future
   - opportunistic sensing

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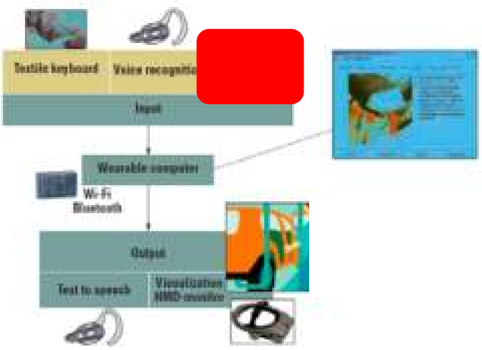
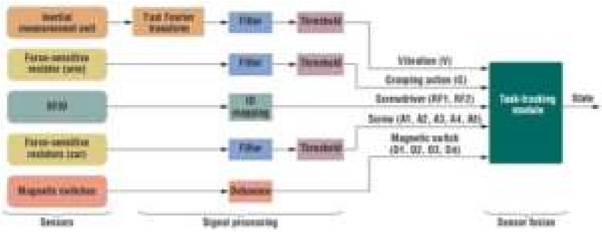
## First Generation Application



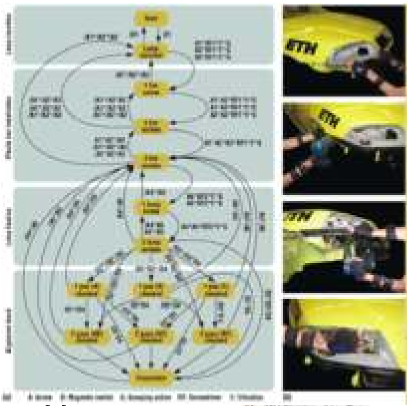

Guide and asses a assembly training task

## The First Generation Setup

## The First Generation Approach




## First Generation Results



except for sensor failures 100% recognition rate

## First Generation Results

Zur Anzeige wird der QuickTime™ Dekompressor „YUV420 codec" benötigt.

1. Thomas Stiefmeier, Daniel Roggen, Georg Ogris, Paul Lukowicz, Gerhard Tr ster, *Wearable Activity Tracking in Car Manufacturing*, IEEE Pervasive Computing, Special issue on Activity-Based Computing - Apr-Jun 08

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## Generation 1.5

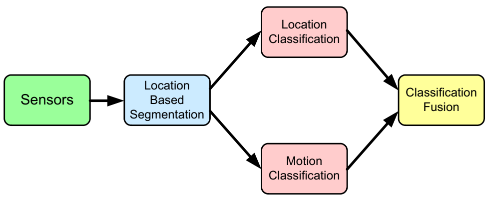
Zur Anzeige wird der QuickTime™ Dekompressor „Motion JPEG OpenDML" benötigt.

1. Stiefmeier, T., Ogris, G., Junker, H., Lukowicz, P., Tr ster, G.: *Combining motion sensors and ultrasonic hands tracking for continuous activity recognition in a maintenance scenario*. In: *Proc. 10th IEEE Int. Symposium on W earable Computers*. ISWC 2006, Montreux, Switzerland. IEEE Computer Society, 2006.

   Ogris, G., Stiefmeier, T., Junker, H., Lukowicz, P., Tr ster, G.: *Using ultrasonic hand tracking to augment motion analysis based recognition of manipulative gestures*. In: *Proc. 9th IEEE Int. Symp. on Wearable Computers*. ISWC 2005. IEEE Computer Society, Washington, DC, USA, 2005, 152-159.

## Approach

Overview on the recognition architecture

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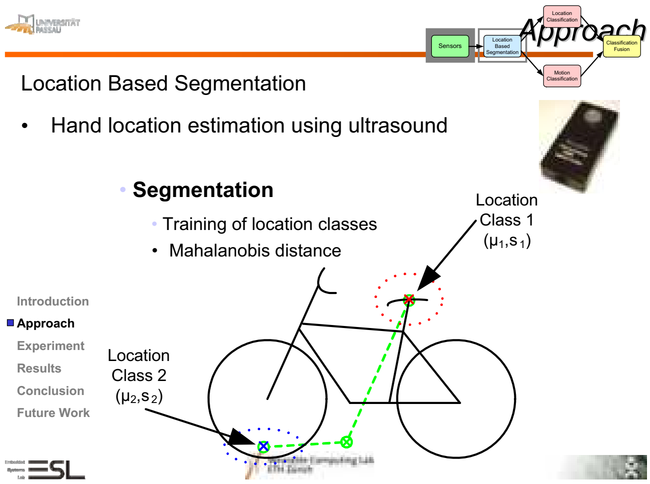
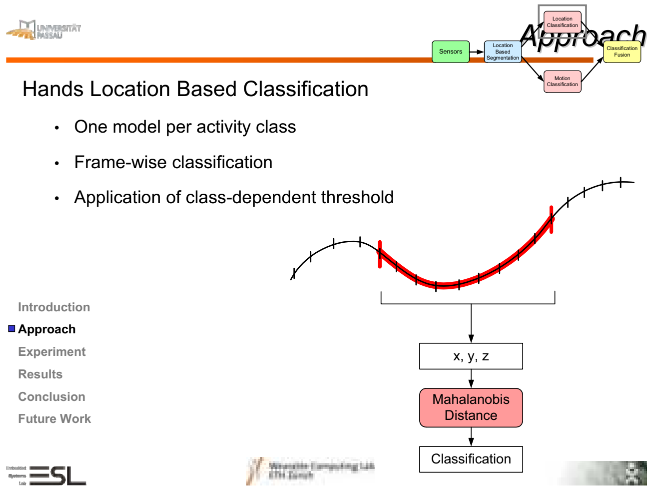
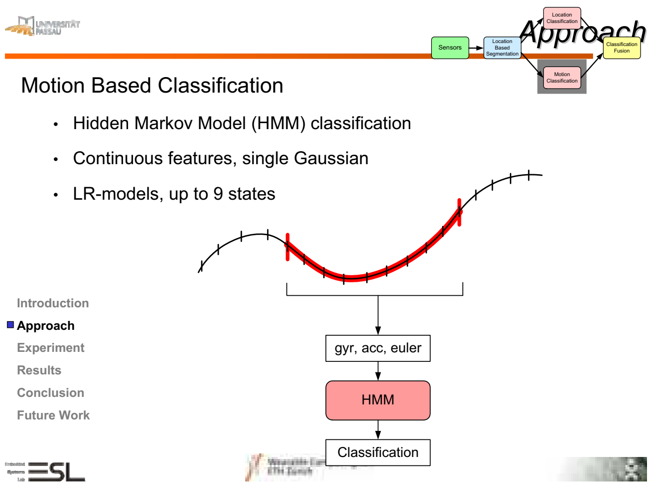
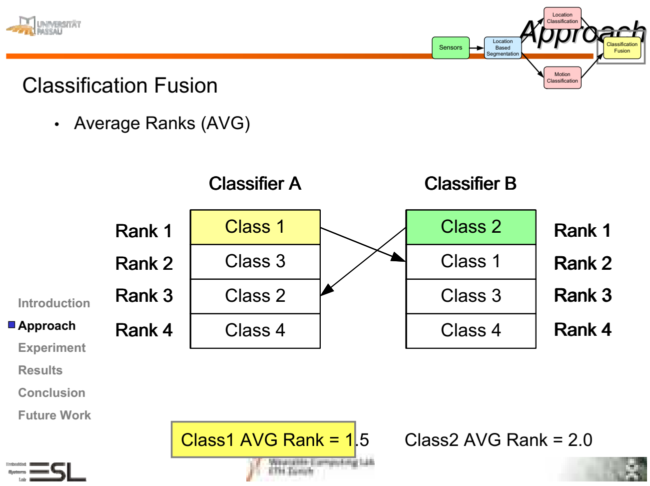
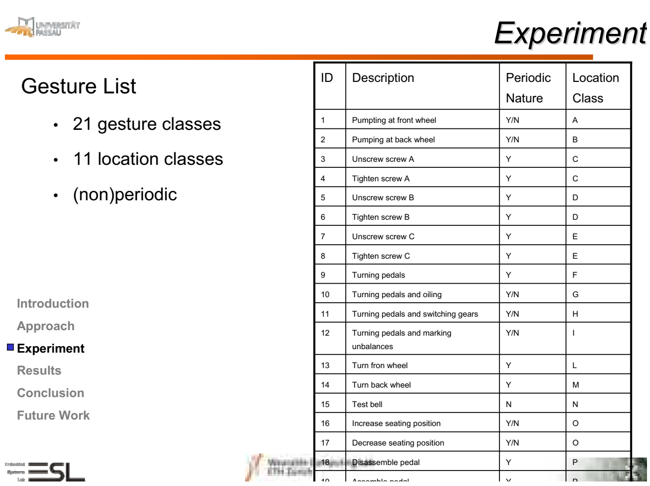
- **Gesture recognition approach**
  - **Location based segmentation of continuous data stream**
  - **Separate classification of segments (Motion + Location)**
  - **Fusion of separate classifications**



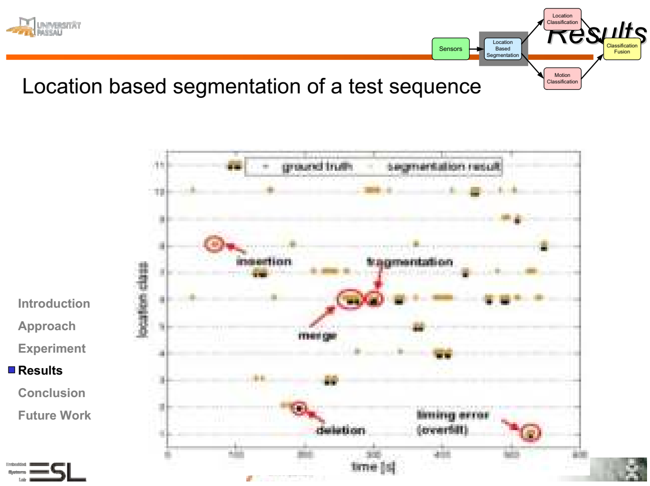



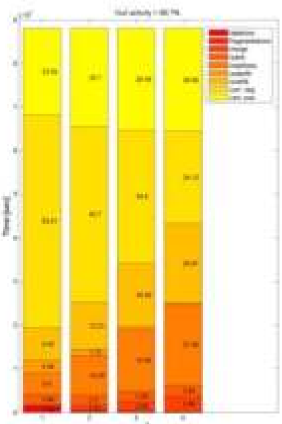



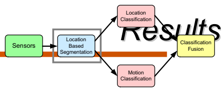




| ID | Description | Periodic Nature | Location Class |
|---|---|---|---|
| 1 | Pumpting at front wheel | Y/N | A |
| 2 | Pumping at back wheel | Y/N | B |
| 3 | Unscrew screw A | Y | C |
| 4 | Tighten screw A | Y | C |
| 5 | Unscrew screw B | Y | D |
| 6 | Tighten screw B | Y | D |
| 7 | Unscrew screw C | Y | E |
| 8 | Tighten screw C | Y | E |
| 9 | Turning pedals | Y | F |
| 10 | Turning pedals and oiling | Y/N | G |
| 11 | Turning pedals and switching gears | Y/N | H |
| 12 | Turning pedals and marking unbalances | Y/N | I |
| 13 | Turn fron wheel | Y | L |
| 14 | Turn back wheel | Y | M |
| 15 | Test bell | N | N |
| 16 | Increase seating position | Y/N | O |
| 17 | Decrease seating position | Y/N | O |
| 18 | Disassemble pedal | Y | P |
| 19 | Assemble pedal | Y | P |





[In percent of POSITIVE/NULL frames]



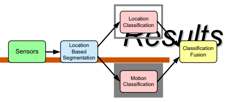

## Results

Applying frame-based evaluation method (by J. Ward) to different segmentation runs (intra mode)

Varying threshold parameter f from 1 to 4

$$\Theta_i = \mu_i + f \cdot \sigma_i$$

---




## Results

### Separate Classification

- Motion based classification using HMM
- Location based classification

| intra | Insertions | Fragment. | Deletions | Substit. | Correct |
|---|---|---|---|---|---|
| Motion | 176.94 | 1.99 | 0.00 | 39.76 | 58.25 |
| Position | 115.41 | 1.39 | 0.00 | 33.00 | 65.71 |

| inter | Insertions | Fragment. | Deletions | Substit. | Correct |
|---|---|---|---|---|---|
| Motion | 190.36 | 2.29 | 0.00 | 37.77 | 60.54 |
| Position | 113.72 | 1.79 | 0.00 | 25.25 | 73.46 |

| external | Insertions | Fragment. | Deletions | Substit. | Correct |
|---|---|---|---|---|---|
| Motion | 193.64 | 2.19 | 0.00 | 42.45 | 55.57 |
| Position | 118.99 | 1.59 | 0.00 | 27.14 | 71.77 |

[In percent of ground truth events]

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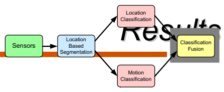


## Results

### Fused Classification

- Application of several fusion schemes

| intra | Insertions | Fragment. | Deletions | Substit. | Correct |
|---|---|---|---|---|---|
| Motion | 176.94 | 1.99 | 0.00 | 39.76 | 58.25 |
| Position | 115.41 | 1.39 | 0.00 | 33.00 | 65.71 |
| PA-AVG | 58.65 | 1.79 | 6.96 | 24.16 | 67.50 |

| inter | Insertions | Fragment. | Deletions | Substit. | Correct |
|---|---|---|---|---|---|
| Motion | 190.36 | 2.29 | 0.00 | 37.77 | 60.54 |
| Position | 113.72 | 1.79 | 0.00 | 25.25 | 73.46 |
| PA-AVG | 69.68 | 1.69 | 5.17 | 17.89 | 75.35 |

| external | Insertions | Fragment. | Deletions | Substit. | Correct |
|---|---|---|---|---|---|
| Motion | 193.64 | 2.19 | 0.00 | 42.45 | 55.57 |
| Position | 118.99 | 1.59 | 0.00 | 33.00 | 71.77 |
| PA-AVG | 65.61 | 1.79 | 4.97 | 21.27 | 71.87 |

[In percent of ground truth events]

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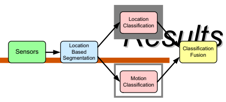


## Results

2nd Rank Analysis

- Consideration of first two choices per classifier
- Potential for improvements

| Intra | Correct | Correct (2nd Rank) |
|---|---|---|
| Motion | 58.25 | 76.14 |
| Position | 65.71 | 91.55 |

| Inter | Correct | Correct (2nd Rank) |
|---|---|---|
| Motion | 60.54 | 76.64 |
| Position | 73.46 | 97.81 |

| External | Correct | Correct (2nd Rank) |
|---|---|---|
| Motion | 55.57 | 72.56 |
| Position | 71.77 | 96.82 |

[In percent of ground truth events]

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---

## 2nd Generation Experiments

Zur Anzeige wird der QuickTime™ Dekompressor „" benötigt.

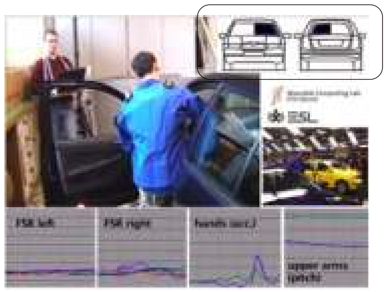
Thomas Stiefmeier, Daniel Roggen, Georg Ogris, Paul Lukowicz, Gerhard Tr ster, *Wearable Activity Tracking in Car Manufacturing*, IEEE Pervasive Computing, Special issue on Activity-Based Computing - Apr-Jun 08

Thomas Stiefmeier, Daniel Roggen, Georg Ogris, Paul Lukowicz, Gerhard Tr ster, accepted for ISWC2008

## 2nd Generation Activitiess

| class ID | class name | location classes | gesture type |
|---|---|---|---|
| 1 | open hood | 1 | b |
| 2 | close hood | 1 | b |
| 3 | open trunk | 5 | b |
| 4 | check trunk | 5 | b |
| 5 | close trunk | 5 | b |
| 6 | fuel lid | 6 | r |
| 7 | open left door | 4,8 | l |
| 8 | close left door | 4,8 | l |
| 9 | open right door | 6,7 | r |
| 10 | close right door | 6,7 | r |
| 11 | open two doors | 6,8 | b |
| 12 | close two doors | 7,8 | b |
| 13 | mirror | 3 | r |
| 14 | check trunk gaps | 5 | b |
| 15 | lock check left | 4,8 | l |
| 16 | lock check right | 6,7 | r |
| 17 | check hood gaps | 2,7 | b |
| 18 | open the spare wheel box | 5 | r |
| 19 | close the spare wheel box | 5 | r |
| 20 | writing | 4,7 | b |

## Sensors: Location



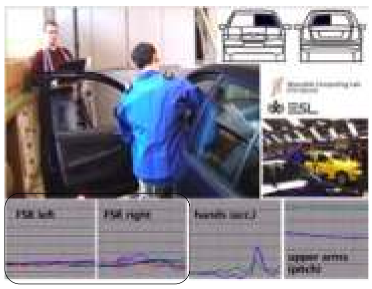

## Sensors: Location

Ubisense tags


## Sensors: Motion

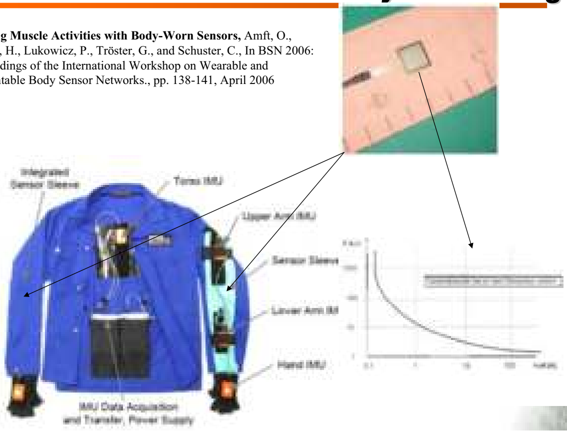

## Sensors: Inertial


## Sensors: FSR for Muscle Activity



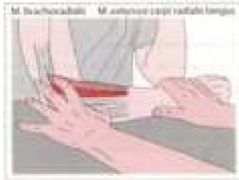
## FSR for Muscle Activity Monitoring

**Sensing Muscle Activities with Body-Worn Sensors,** Amft, O., Junker, H., Lukowicz, P., Tröster, G., and Schuster, C., In BSN 2006: Proceedings of the International Workshop on Wearable and Implantable Body Sensor Networks., pp. 138-141, April 2006




## Arm Actions with FSRs

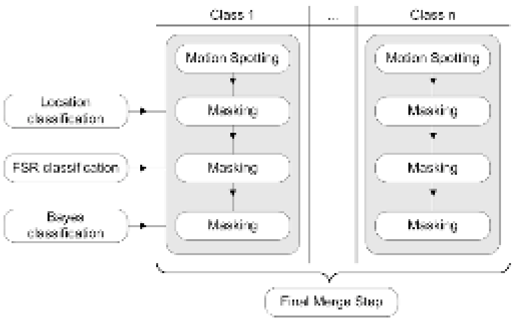
Zur Anzeige wird der QuickTime™ Dekompressor „mpeg4" benötigt.

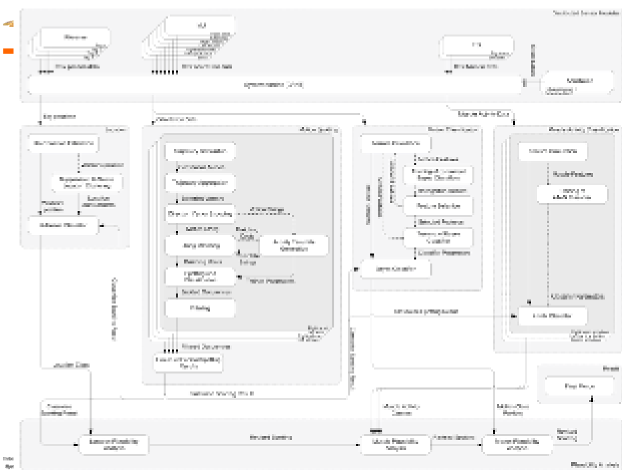


**Sensing Muscle Activities with Body-Worn Sensors,** Amft, O., Junker, H., Lukowicz, P., Tröster, G., and Schuster, C., In BSN 2006: Proceedings of the International Workshop on Wearable and Implantable Body Sensor Networks., pp. 138-141, April 2006

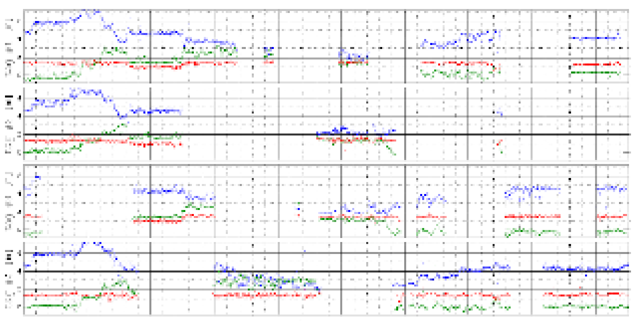
## Recognition Method

scalable in the number of sensors and activities



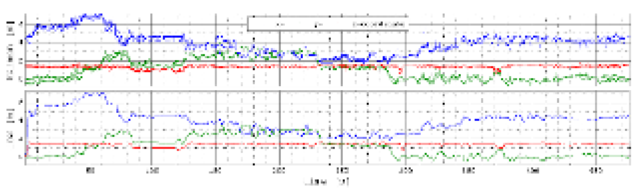



## Location Raw Data



| class ID | class name | class ID | class name |
|---|---|---|---|
| 1 | head | 5 | trunk |
| 2 | front left | 6 | rear right |
| 3 | inside | 7 | front right |
| 4 | rear left | | |

## Smoothed and Filtered Result



| class ID | class name | class ID | class name |
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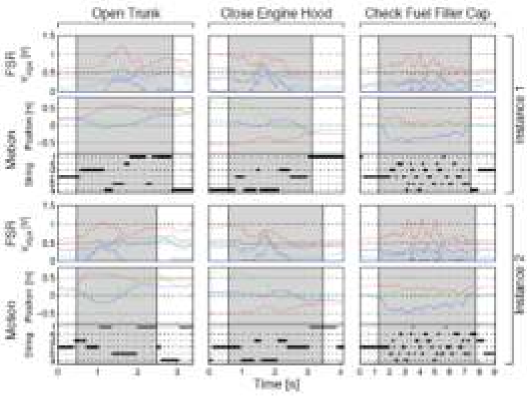
| 1 | head | 5 | trunk |
| 2 | front left | 6 | rear right |
| 3 | inside | 7 | front right |
| 4 | rear left | | |

## Moption Signal

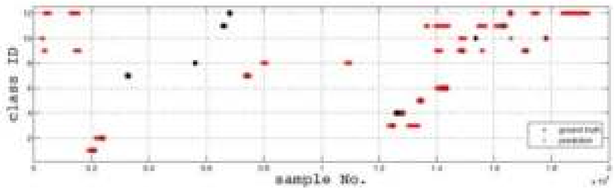
## Motion Recogntion Method


T. Stiefmeier, D. Roggen, and G. Tröster. Gestures are strings: Efficient online gesture spotting and classification using string matching. In *Proc. of the Int. Conf. on Body Area Networks*, Jun 2007.

## Combined Signal Examples

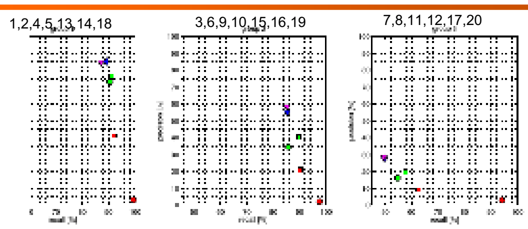



## Results




| | correct | deletions | insertions | substitutions | fragmentations |
|---|---|---|---|---|---|
| motion spotting | 80.4 | 1.3 | 427.3 | 22.7 | 4.5 |
| muscle plausibility analysis | 76.2 | 8.1 | 175.1 | 19.6 | 5.8 |
| location plausibility analysis | 80.7 | 8.8 | 140.1 | 15.6 | 5.0 |
| final | 70.3 | 18.7 | 52.4 | 11.2 | 2.0 |

## Results




- motion spotting (red square),
- muscle activity classification (red circle),
- muscle plausibility analysis (green circle),
- location plausibility analysis (green square),
- location and muscle plausibility analysis (blue diam
- motion plausibility analysis (lila triangle).

| class ID | class name | location classes | gesture type |
|---|---|---|---|
| 1 | open hood | 6 | b |
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| 3 | open trunk | 5 | b |
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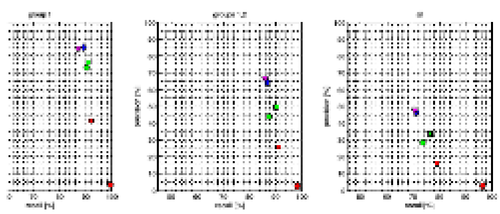
## Results

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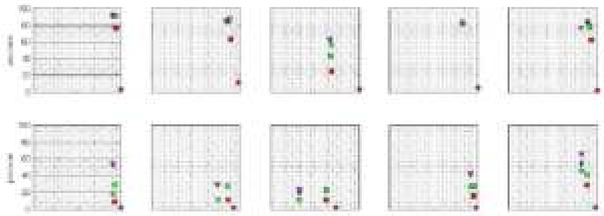
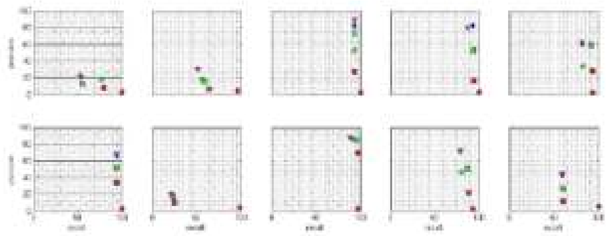
## Results



## Results



## Overview

1. First Generation
   - heavily augmented environment in training applications
2. Generation 1.5
   - simulated repair task with wearable sensors
3. Second Generation
   - Initial spotting of activities in real world production scenario (offline)
4. Third Generation
   - real time reliable spotting of activities in production scenario
5. The Future
   - opportunistic sensing

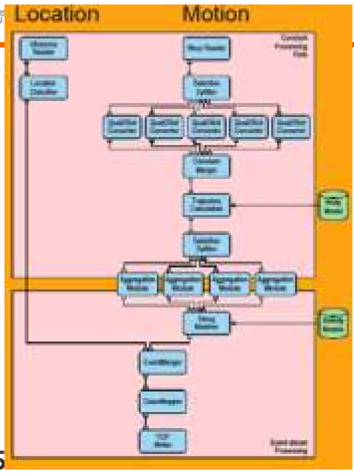
## 3rd Generation

Zur Anzeige wird der QuickTime™ Dekompressor „" benötigt.

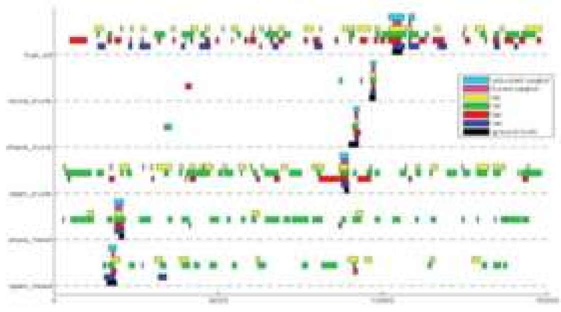
## 3rd Generation

1. Integration of motion spotting into CRN Toolbox
2. Integration of location classification into CRN Toolbox
3. Simplified to two sensor domain
   - Improved fusion of sensor domains
4. **Improved accuracy**
5. **Real-time implementation**

## Implemetation



## 3rd Generation Results



## Overview

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4. Third Generation
   - real time reliable spotting of activities in production scenario
5. The Future
   - opportunistic sensing

## Main Stream, Realistic Systems


## Main Stream, Realistic Systems


MOTOROLA BT headset


Nike/Apple shoe sensor

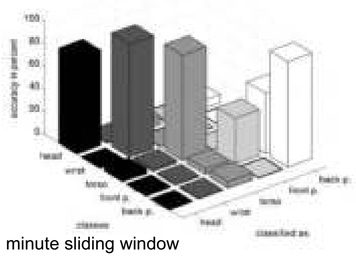

CASIO watch with 5 sensors (acceleration, digital compass, light, air pressure)

**how do we use this for activity recogniton ?**


Apple IPhone: motion, proximity, light, humidity sensor+ mic+camera

## On Body Position Recognitio

real life data sets (around 3 hours each)



1 minute sliding window


K. Kunze, P. Lukowicz, ISWC 2007

## Outlook: Placement Independence

Gym Exercises
q lat machine
r pecotrial
s sholder press
t upper back
u arm extension
v arm curl
w pull down
i chestpress


| Modality | Same | Trained on 1 | Trained on 2 |
|---|---|---|---|
| Acceleration | 97% | 24% | 31% |
| Combined | - | 74% | 82% |

*K. Kunze, P. Lukowicz accepted for UBICOMP 2008*

WEARIT @WORK

# Supporting Mobile Workers in Car Production by Wearable Computing

## Applied Context Detection

Karsten Matysczok/Unity & Iñaki Maurtua/Tekniker

UNITY AG

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## Table of Content



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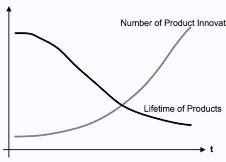
## Introduction

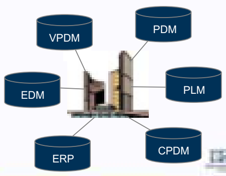
**Market Description**

- Increasing dynamics of innovation and a reduction of the product lifetimes
- Products and the production processes become more and more complex
- High demands on production processes and on involved employees




**Current Challenges**

- Omnipresent availability of production related information
- Usage of various IT-systems and databases
- Information is basically available, but the access is generally difficult, time intensive and limited to dedicated stationary PCs

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## Introduction

**Actual Needs**

- Development of a wearable device, which allows the end users to access production related data every time and everywhere
- Improvement of the current interface to the computer
- Easy and intuitive access even of not trained users to product and production processes data
- Uncomplicated integration of the solution (IT infrastructure, software and databases, existing company workflows)

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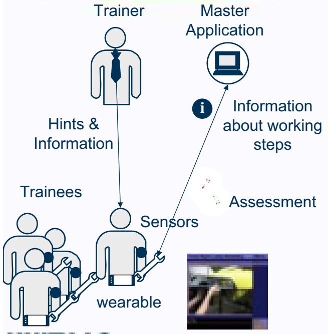
## Covered Production Scenarios
### Training




**Individualised Training**

- Trainees use wearable computers
  - Context-related pattern recognition
  - information about the current working step
  - Assessment of training results
- Trainer coordinates trainees
  - Connected via master application
  - Hints & information via wireless communication

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## Covered Production Scenarios
### Training

**Major Findings**

- Improvement of users performance when using wearable with implicit interaction
  - Assembly tasks were performed faster and with less error (67 seconds less in average than paper-based information)
- Users did not learn faster using a wearable system
  - People were able to learn faster through paper-based support
  - Difference was neglectable compared to those using context based interaction
- Voice recognition-based interaction was the preferred interaction modality by workers
- Workers preferred graphical information to text
- Workers found the system very useful when doing a complex task
  - allowing hands free access to information
  - avoiding dispensable movements in order to check information

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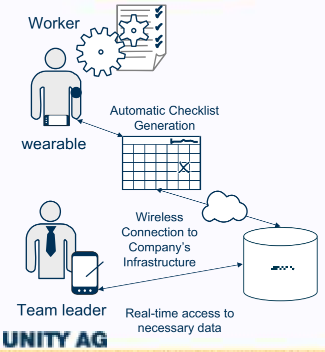
## Covered Production Scenarios
### Quality Assurance




**Automatic checklist generation for quality assurance**
- Test recognition
- Recording of results
- Link to company's infrastructure
- Real-time access to data and test results
- Collaboration among workers

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## Covered Production Scenarios
### Quality Assurance

**Major Findings**
- Wearable systems can support the quality assurance by recording of the performed quality checks and documenting the corresponding results
  - Discrepancy of components on the assembly line
  - Alignment of the components and their fittings
  - Control of the correctness
  - Completeness of operation sequences
- Elimination of paper during full checking activity
- Reduction of mental workload associated to report fulfillment
  - Automatic documentation of all performed actions and quality checks
  - Safeguarding that all required quality checks are performed

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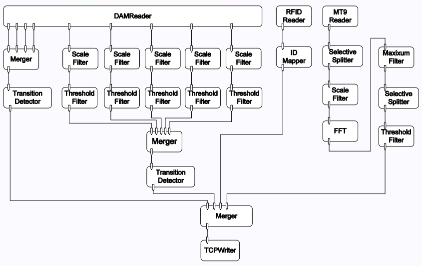
## Context Detection




**Network**
- Processing of force sensitive resistors and reed switches
- Threshold operator is applied to detect the status of the respective sensor
- CRN tasks dealing with the RFID reader
- Merger task sends streams to the JContextAPI using a TCP/IP connection

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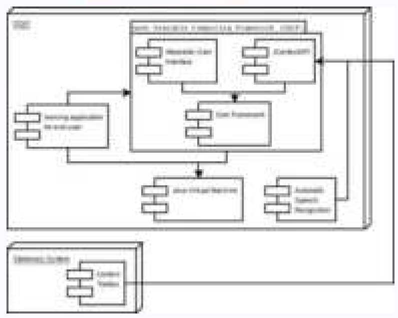
## Used Software Framework



**OWCF**
- Application is modeled internally as a finite state machine
- Collected sensor data is processed by context toolbox
- Application simply registers a set of listeners within JContextAP
- The JContextAPI acts also as interface with the Automatic Speech Recognition System

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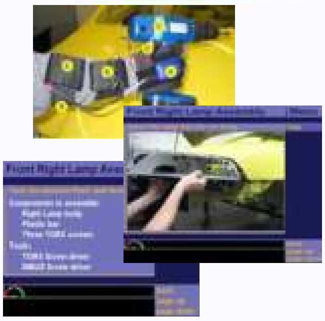
## Current Status of Implementation



**Current Pilot**
- OQO technical characteristics offer enough computational power to fully support the applications
  - Network
  - Bluetooth
  - External VGA output
- Carl Zeiss binocular look-around head mounted display
- Sony Ericson HBH-300 Bluetooth headset to interact with the prototype application via voice
- Main navigation mechanism is implicit, i.e. the system detects task completion and goes on to the next step information

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## Conclusion and Future Work

**Conclusion**
- Current project results show how wearable technology can allow an efficient, successful working environment by providing ubiquitous, mobile access to production process-related information where and when necessary
- Developed prototypes enables a context-sensitive provision of necessary information to the workers
- By supporting training procedures and documenting the performed quality checks, high benefits are expected

**Future Work**
- Refinement of the solution according to end-users feedback
- Conduction of further tests and field studies within Škoda in order to gather enough knowledge to evaluate the prototype more comprehensively

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## Wearable Computing in Healthcare – from an idea to a working system in daily business

Dr. Kurt Adamer
Gespag/Steyr/Austria

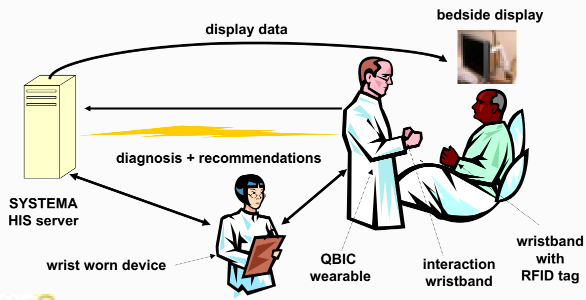
ICE Workshop, Lisbon 25.6.2008

## Motivation

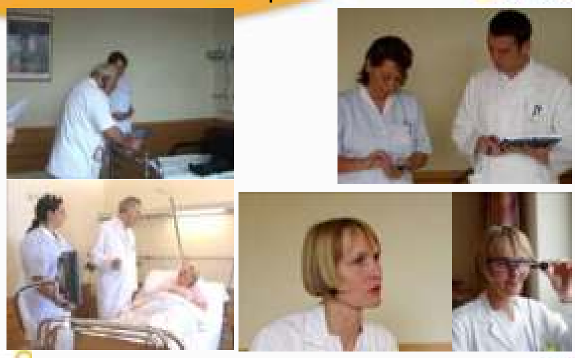
- Ward round is the pivotal point in the hospital
- Decisions taken and orders made have to be documented
- Time pressure, up to 14-15 patients within 20 minutes
- Current work flow and information processing methods result in a great deal of post processing work

## Healthcare - User acceptance

Back office features at the patients bedside




## Healthcare - user acceptance



## Prototype evaluation
Setup

Procedure:

1. Doctor and nurse approach bed
2. Doctor greets/identifies patient
3. Doctor browses documents
4. Doctor examines patient
5. Doctor makes examination request
6. Nurse enters request details

**10 doctors, 9 nurses**
**4 procedure runs each**

Research issues:
- Practical problems/advantages with PDA and gesture interaction
- Potential effect on work efficiency
- Potential effect on patient contact

## Healthcare prototype evaluation
Results

**Gesture interaction**
- Many beginner/learning problems with timing, shape and concept
- Probable cause for learning problems: lacking of direct feedback
- General skepticism because of gesture size

**PDA interaction**
- No problems with interaction or workflow

**Potential work efficiency**
- Immediate entering and authorization of examination request less errors and avoidance of redundant work

**Patient contact**
- Fear of looking like a fool in front of the patient
- Too much attention needed by the system (depending on department)

## Improving the system

- Lack of robustness and reliability in daily business
- To complex – to many components

⇒ Further and extensive multilevel tests
⇒ Simplifying the design
⇒ Different approach of interaction

## Aim and Requirement

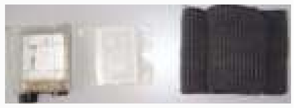
- Simple Interaction Device for:
  - Scrolling through a menu
  - Selecting/deselecting items
- Requirements and exclusions
  - Hands disinfected during interaction
  - Wrist worn keyboards and PDAs requiring the use of both hands are not suitable
  - Voice control would interfere with the conversation

⇒ Concept of a capacitive sensor placed under the doctors coat to detect small gestures performed in the proximity of the sensor location close to the surface of the coat

## System description

- Doctor wears personal RFID tag for identification
- Patients have their tags beside the bed
- Doctor scans the RFID tags
  - Indicate to HCI which doctor is performing actions on which patient
  - HCI prompts corresponding documents for the patient
  - Doctor moves hand above the pad integrated underneath the coat for interaction with the application
- Grado Zero Espace designed two 7 channel pads (small and larger version)
  - Big pad is controlled by hand
  - Small one is controlled by one or two fingers
  - Pads are attach to doctor's coat by fasteners – removable for cleaning

## Using a RFID Reader and the sensor pad



Doctor/Patient RFID check-in hardware
- RFID Reader Board, RFID Tag and board in wristband

Capacitive sensor pad hardware
- pad and measuring board

## Major Outcome - Gesture Evaluation

- A data set has been recorded while wearing the touchpad strip on the lower right side of the coat for 59.7 minutes with 24542 data samples
- During 6 minutes the device was used intentionally for controlling an application
- During the rest of the time the systemwas just worn while conducting everyday-activities like sitting, walking, and gesticulating
- Sliding/clicking The UP/DOWN commands are producedby sliding over the touchpad strip in the respective direction, whereas touching the strip for ashort time ("clicking") triggers the OPEN- and CLOSE commands alternatingly (it is intended that the controlled GUI-application knows if a document is open or not and therefore knows by itself which action is possible).

Results:

- A high precision can be reached for the three commands but unintended contact with the touchpad strip during normal everyday activities caused a high rate of false positives
- In particular the OPEN/CLOSE commands were triggeed frequently without intention

## Microgestures

- In addition to the sliding movements small gestures conducted by the hand are detected
  - When opening the hand on the touchpad strip, spreading thumb and fingers, an OPEN command is issued
  - Similarly, closing the hand produces the CLOSE command

Results:

- This algorithm shows an higher recognition rate while drastically reducing the number of false positives, in particular for the OPEN and CLOSE commands
- The microgestures conducted by the hand are perfectly distinguished from unintended contact with the device

## System Test in Bundeskrankenhaus, Steyr

- System test has been performed from May 5th to May16th, 2008
- The system was installed in a patient room with two patient beds
- Patients documents were displayed on a bed-side PC

Results:

- During the test period, the doctors used the system twice every day
- In most cases, the doctors were satisfied with the system, and the patients were also happy to take a look at their own documents easily from the bed
- However, we could not judge the rate of error triggers, as patients' privacy disabled recording doctor's actions by a camera

## Further steps

- A demonstration of the system was held on May 20th & 21th in the cafeteria of the hospital
- The system was shown to doctors and nurses for test purposes with positive feed-back
- A further student test was performed from May 26th to May 30th overcoming the privacy issue
- The system will be further used
- The roll-out is planned

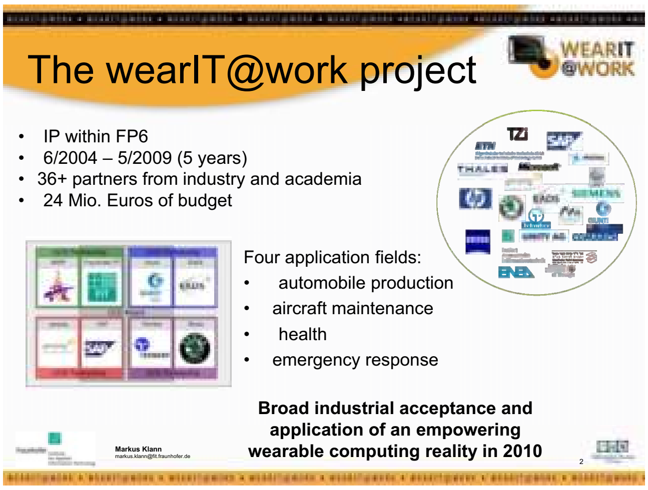
## Thank you for your attention

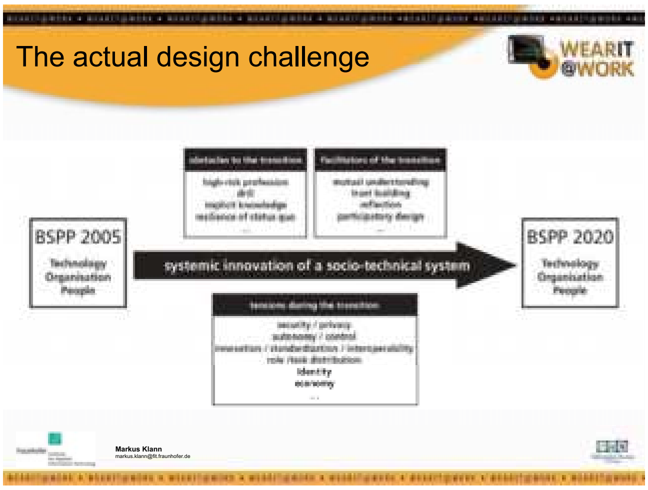
**For further information please contact:**

**Dr. Kurt Adamer [Kurt.Adamer@gespag.at]**

www.wearitatwork.com – **Project homepage**


WEARIT @WORK
Designing Wearables for Emergency Response
An approach to systemic innovation
Markus Klann, Fraunhofer FIT
ICE conference
Lisbon, 25.6.2008
Markus Klann
markus.klann@fit.fraunhofer.de


The wearIT@work project
WEARIT @WORK
• IP within FP6
• 6/2004 – 5/2009 (5 years)
• 36+ partners from industry and academia
• 24 Mio. Euros of budget
Four application fields:
• automobile production
• aircraft maintenance
• health
• emergency response
Broad industrial acceptance and application of an empowering wearable computing reality in 2010
Markus Klann
markus.klann@fit.fraunhofer.de
2


The actual design challenge
WEARIT @WORK
BSPP 2005
Technology
Organisation
People
systemic innovation of a socio-technical system
BSPP 2020
Technology
Organisation
People
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Creating technology
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4


Appropriating technology
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Markus Klann
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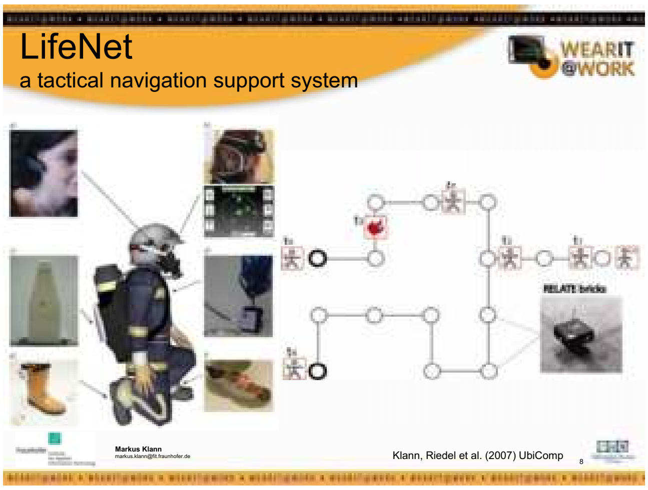
Reflection in Action
WEARIT @WORK
Markus Klann
markus.klann@fit.fraunhofer.de
6


From vision to reality:
WEARIT @WORK
Markus Klann


LifeNet
a tactical navigation support system
WEARIT @WORK
RELATE bricks
Markus Klann
Klann, Riedel et al. (2007) UbiComp


From vision to reality:
prototyping the user experience
WEARIT @WORK
Paper: maximum participation
VR: interactivity, ongoing processes and fun longitudinal&latitudinal
„Living Lab" maximum validity
→ facilitating playful reflection on
technology adoption and organizational change
Markus Klann


Empirical Research since 2004
WEARIT @WORK
Numerous observational studies and interviews, including large-scale
Hands-on training in operational fire fighting and incident command
Markus Klann


war games: fighting fire on paper
WEARIT @WORK
Markus Klann


Virtual intervention simulations
WEARIT @WORK
Virtual Fire Fighter
with LifeNet System
Virtual Simulation of the
Paris Fire Brigade's Training Site
Permanent installation at BSPP
since autumn 2007
Markus Klann


Exercise simulations
WEARIT @WORK
Markus Klann
markus.klann@fit.fraunhofer.de
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Some Results
WEARIT @WORK
↑ Based on established cultural practise
↑ Instructive
↑ Engaging
↑ Easy switching between action and reflection
↑ Rich in feedback
↑ Good acceptance of simplicity
↕ Bird eye view
↓ Poor in interactivity
↓ Requiering big effort
↓ Small scale operations only
↓ Simulation Artefacts
↑ Based on established cultural practise
↑ Instructive
↑ Engaging
↑ Rich in feedback
↑ Rich interactivity
↑ Requiering little effort
↑ Scales fairly well
↑ Longitudinal and latitudinal studies
↓ Considerable initial development effort
↓ Static use
↓ Lacking haptic aspects
↓ Possibly suggestive
↓ Possible rejection of simplicity
↑ Based on established cultural practise
↑ Instructive
↑ Engaging
↑ Rich in feedback
↑ Rich interactivity
↑ Real haptics
↑ Real activities and equipment
↓ Requiering big effort
↓ Scales not too well
↓ Difficult to observe
Markus Klann
markus.klann@fit.fraunhofer.de
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Cultural change
WEARIT @WORK
Rescue or perish
… or maybe not …
Incident Command Training:
„Sauver ou périr c'est bien joli, mais mieux vaut sauver sans périr!"
„To save or die that's all nice and well but better even is saving without dying."
Markus Klann
markus.klann@fit.fraunhofer.de


WEARIT @WORK
Questions?
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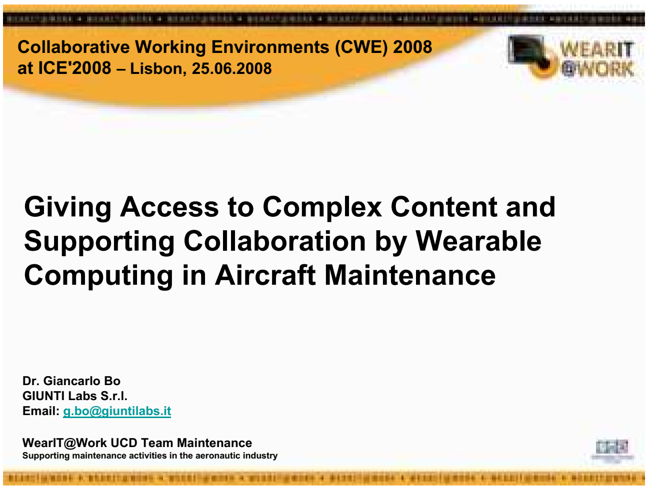
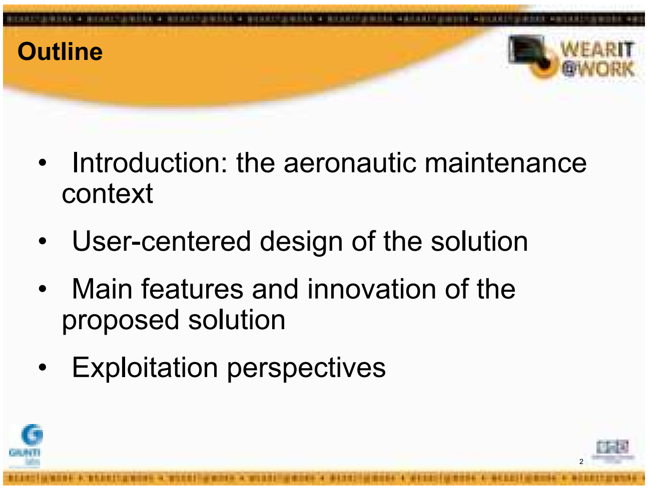
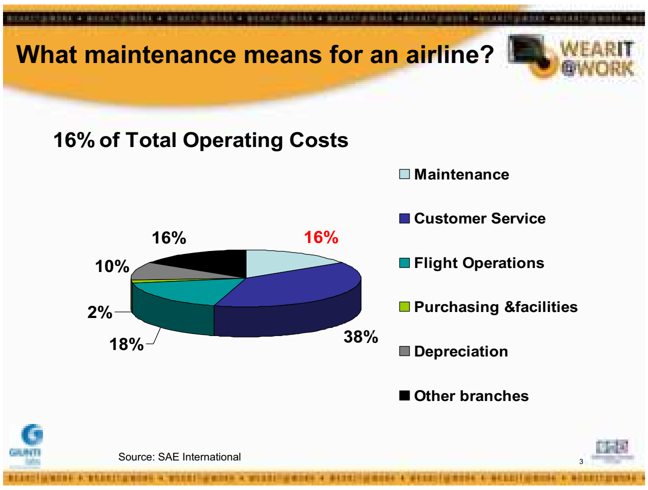
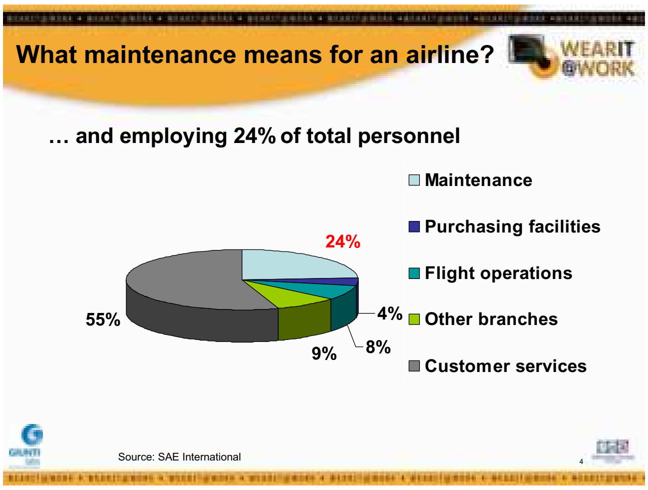
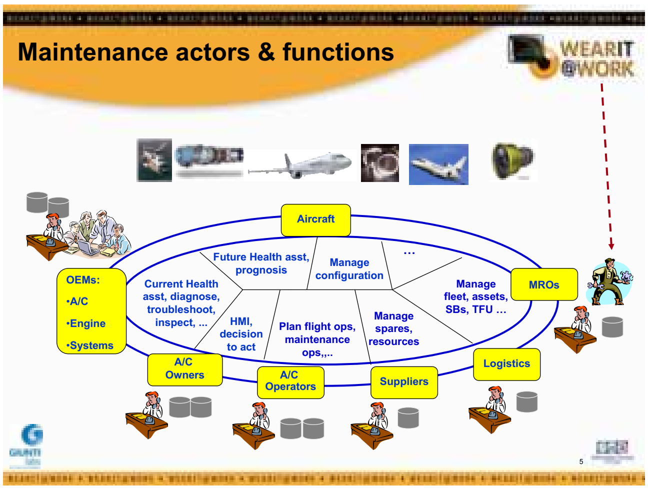
16


Collaborative Working Environments (CWE) 2008
at ICE'2008 – Lisbon, 25.06.2008
WEARIT @WORK
Giving Access to Complex Content and Supporting Collaboration by Wearable Computing in Aircraft Maintenance
Dr. Giancarlo Bo
GIUNTI Labs S.r.l.
Email: g.bo@giuntilabs.it
WearIT@Work UCD Team Maintenance
Supporting maintenance activities in the aeronautic industry

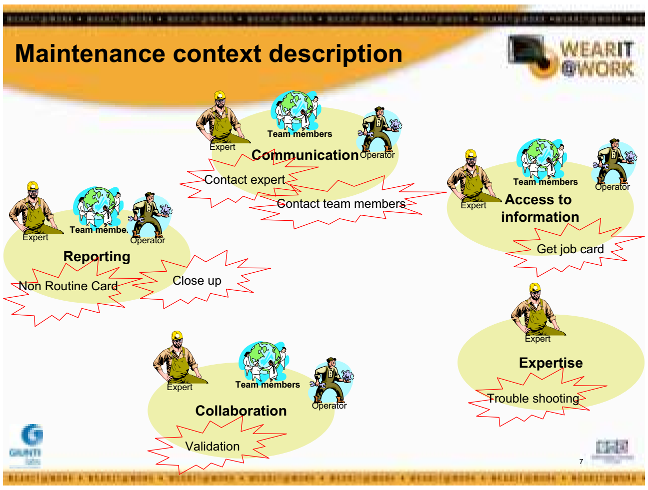

Outline
WEARIT @WORK
• Introduction: the aeronautic maintenance context
• User-centered design of the solution
• Main features and innovation of the proposed solution
• Exploitation perspectives
2

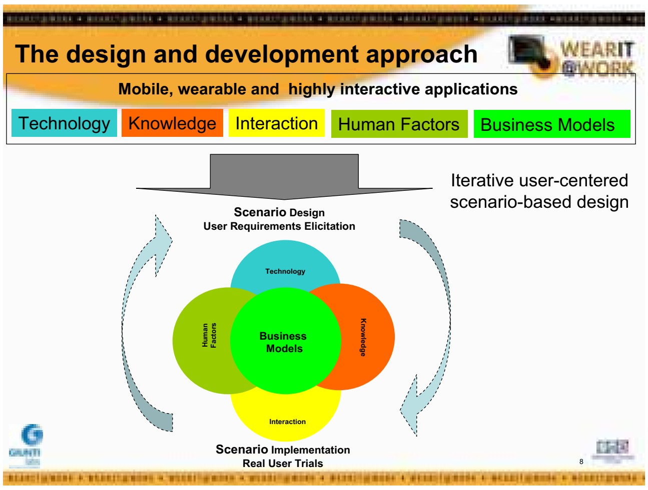

What maintenance means for an airline?
WEARIT @WORK
16% of Total Operating Costs
Maintenance
Customer Service
Flight Operations
Purchasing &facilities
Depreciation
Other branches
16%
16%
10%
2%
18%
38%
Source: SAE International
3

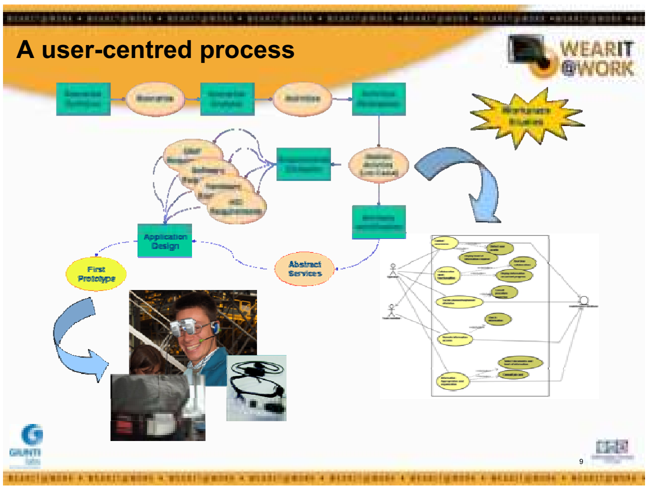

What maintenance means for an airline?
WEARIT @WORK
… and employing 24% of total personnel
Maintenance
Purchasing facilities
Flight operations
Other branches
Customer services
24%
55%
4%
9%
8%
Source: SAE International
4

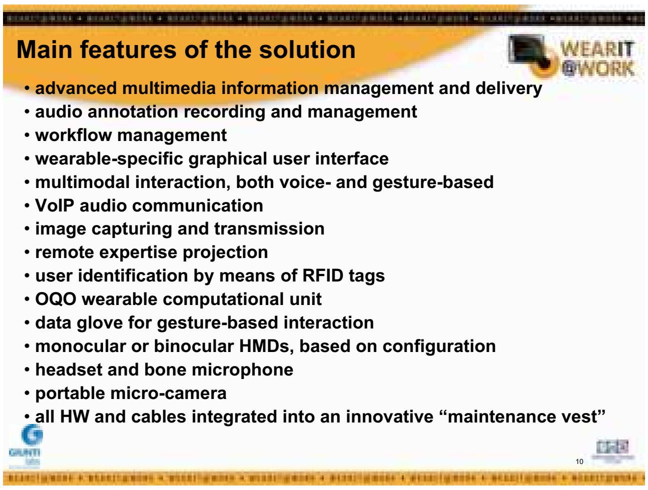

Maintenance actors & functions
WEARIT @WORK
Aircraft
OEMs:
•A/C
•Engine
•Systems
Current Health asst, diagnose, troubleshoot, inspect, ...
Future Health asst, prognosis
Manage configuration
…
Manage fleet, assets, SBs, TFU ...
MROs
HMI, decision to act
Plan flight ops, maintenance ops,...
Manage spares, resources
A/C Owners
A/C Operators
Suppliers
Logistics
5


Aircraft maintenance context
from mobile worker point of view
WEARIT @WORK
Traditional mobile maintenance workplaces are isolated from background information systems
– 20 to 50% of a maintenance task is lost in searching for information
– Poor communication system on working area
– Large distance to cover to communicate with team members
– No direct access to remote expertise on line - which means lost of time
Complex products are produced industrially but maintained and repaired by hand
– In 85% of maintenance tasks, operators need to be hand-free
– 100% of operators regularly perform their task in uncomfortable positions or environment
Status analysis Requirements Modules development
6


Maintenance context description
WEARIT @WORK
Team members
Expert
Communication
Operator
Contact expert
Contact team members
Team members
Expert
Operator
Access to information
Get job card
Expert
Team members
Operator
Reporting
Non Routine Card
Close up
Expert
Expertise
Trouble shooting
Expert
Team members
Operator
Collaboration
Validation
7

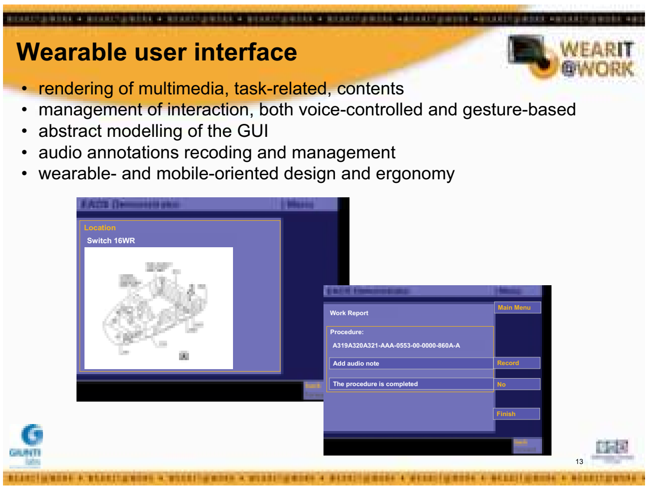

The design and development approach
WEARIT @WORK
Mobile, wearable and highly interactive applications
Technology
Knowledge
Interaction
Human Factors
Business Models
Iterative user-centered scenario-based design
Scenario Design
User Requirements Elicitation
Technology
Human Factors
Business Models
Knowledge
Interaction
Scenario Implementation
Real User Trials
8


A user-centred process
WEARIT @WORK
First Prototype
Application Design
Abstract Services
9

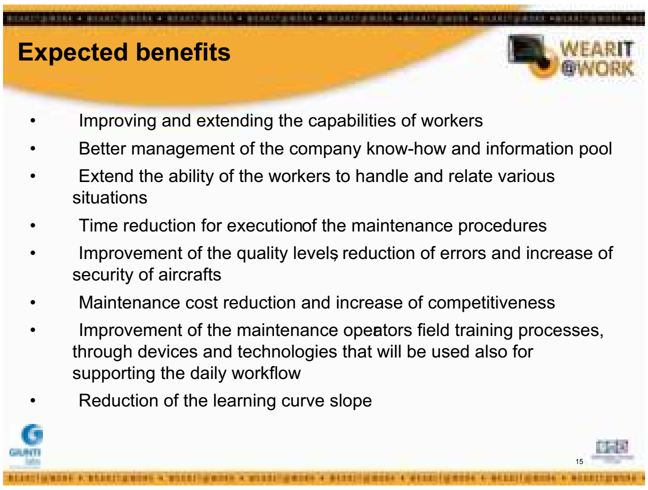

Main features of the solution
WEARIT @WORK
• advanced multimedia information management and delivery
• audio annotation recording and management
• workflow management
• wearable-specific graphical user interface
• multimodal interaction, both voice- and gesture-based
• VoIP audio communication
• image capturing and transmission
• remote expertise projection
• user identification by means of RFID tags
• OQO wearable computational unit
• data glove for gesture-based interaction
• monocular or binocular HMDs, based on configuration
• headset and bone microphone
• portable micro-camera
• all HW and cables integrated into an innovative “maintenance vest”
10

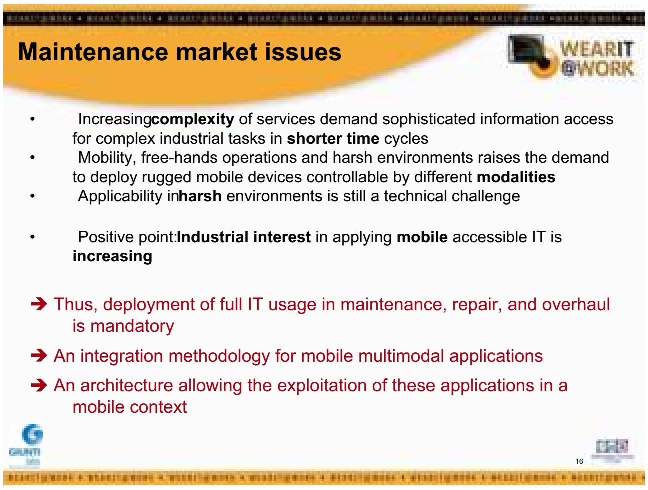

Advanced technical documentation authoring and management
WEARIT @WORK
Phase 1: Technical contents templating and authoring from existing S1000D components
S1000D contents repositories.
Phase 3: Multidevice delivery of complex contents, with multimodal interaction (speech, gesture).
Phase 2: Linking of S1000D procedures to 3D aircraft and working environment models.
11


Collaboration and communication
WEARIT @WORK
• The collaboration module is developed as part of the project.
• The collaboration client is used fo enabling VoIP, video stream, chat and file transfer.
12

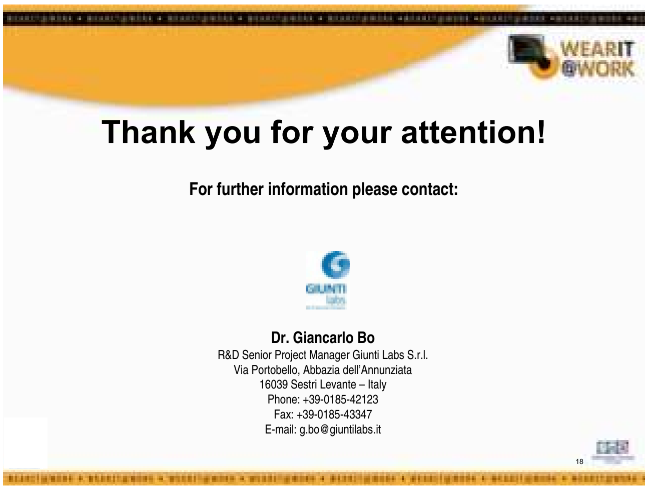

Wearable user interface
WEARIT @WORK
rendering of multimedia, task-related, contents
management of interaction, both voice-controlled and gesture-based
abstract modelling of the GUI
audio annotations recoding and management
wearable- and mobile-oriented design and ergonomy
Location
Switch 16WR
Work Report
Procedure:
Add audio note
The procedure is completed
Main Menu
Record
No
Finish
13


The maintenance vest
WEARIT @WORK
Reconfigurable clothing
Side regulation, for better wearability
Mesh zones, to increase transpiration
Tubular arm structure, X-structure, for bodyclose-fitting and better weight carrying .
14


Expected benefits
WEARIT @WORK
Improving and extending the capabilities of workers
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
Improvement of the maintenance operators field training processes, through devices and technologies that will be used also for supporting the daily workflow
Reduction of the learning curve slope
15


Maintenance market issues
WEARIT @WORK
Increasing complexity of services demand sophisticated information access for complex industrial tasks in shorter time cycles
Mobility, free-hands operations and harsh environments raises the demand to deploy rugged mobile devices controllable by different modalities
Applicability in harsh environments is still a technical challenge
Positive point: Industrial interest in applying mobile accessible IT is increasing
Thus, deployment of full IT usage in maintenance, repair, and overhaul is mandatory
An integration methodology for mobile multimodal applications
An architecture allowing the exploitation of these applications in a mobile context
16


Value chain and exploitation paths
WEARIT @WORK
Processes
Documentation
Technology
Services
Product Lifecycle Management improvement
17


WEARIT @WORK
Thank you for your attention!
For further information please contact:
GIUNTI labs
Dr. Giancarlo Bo
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Via Portobello, Abbazia dell'Annunziata
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## ICE 2008

**Wearable Computers: Do They Really Empower the Mobile Worker?**

**Dr. Edna Pasher**
ICE 2008
Lisbon, Portugal
June 23-25, 2008

Edna Pasher Ph.D & Associates
Management Consultants

**The wearIT@work project is based on a user centered design UCD approach and thus emphasizes the importance of studying users' acceptance of the wearable computer, its potential impact on social, organizational and human factors as well as usability issues**

Edna Pasher Ph.D & Associates
Management Consultants

## Our Role

Recommendations for the designers and developers on how the wearable should be in relation to social aspects

The guidelines set forth principles ("ground rules") for design of the device and the user-computer interface.

Edna Pasher Ph.D & Associates
Management Consultants

## Importance of Social Aspects

- Maximizing the success of the **introduction, user acceptance and adoption of the wearable computer.**
  - Especially in case of an innovative technology such as the wearable computer
- **A system* design which explicitly addresses social factors can enhance implementation success rate.**

* The term "system" covers not only the device but also the technology diffusion process, work processes, cultural issues, organisational aspects.

Edna Pasher Ph.D & Associates
Management Consultants

## Neil Postman's Media Ecology

- All technological change is a trade-off
  - For every advantage a new technology offers, there is always a corresponding disadvantage
  - Examples: cell phones, TV, computers
- Examine effects technology has on our interactions with our surroundings, or ***ecology***

Edna Pasher Ph.D & Associates
Management Consultants

## John Nesbitt: Hi Tech-Hi Touch

- Claim: Increasing gap between technological and social change

THEREFORE…

- Major success factor of technology
  - Design that meets surging, cutting-edge momentum of increasingly technological world, or **Hi-Tech**
  - Design that meets the human needs of personal growth and social relations, or **Hi-Touch**

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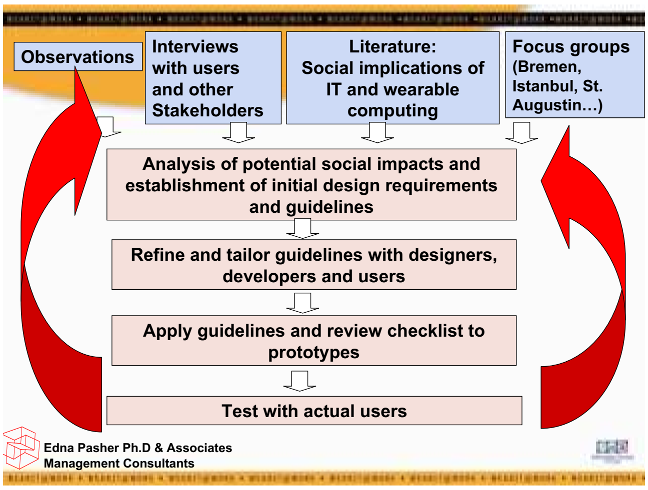
Observations
Interviews with users and other Stakeholders
Literature: Social implications of IT and wearable computing
Focus groups (Bremen, Istanbul, St. Augustin…)
Analysis of potential social impacts and establishment of initial design requirements and guidelines
Refine and tailor guidelines with designers, developers and users
Apply guidelines and review checklist to prototypes
Test with actual users
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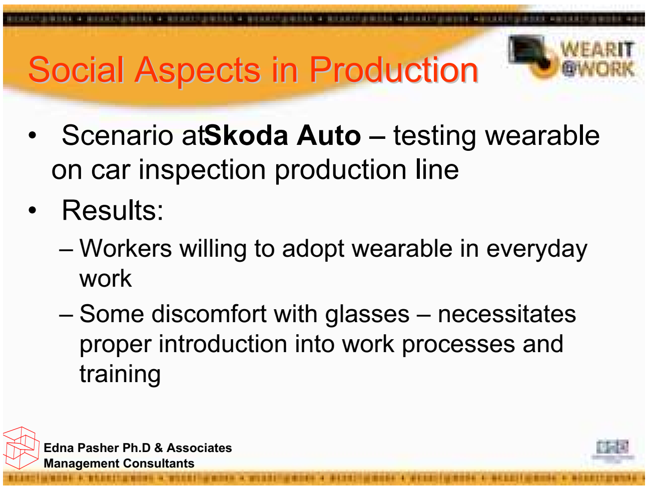
Social Aspects in Production
WEARIT @WORK
• Scenario at Skoda Auto – testing wearable on car inspection production line
• Results:
– Workers willing to adopt wearable in everyday work
– Some discomfort with glasses – necessitates proper introduction into work processes and training
Edna Pasher Ph.D & Associates
Management Consultants


Social Aspects in Healthcare
WEARIT @WORK
• Scenario at Gespag Hospital in Steyr, Austria during surgical ward rounds
• Results:
– Patient able to see medical file in real time – notice mistakes in file, be part of wellness process with doctor
– Nurses occupied with tablet PC during ward rounds
→ lower interpersonal contact between nurse and patient
→ part of the learning curve associated with such a system
– Increased physical contact between doctor and patient
Edna Pasher Ph.D & Associates
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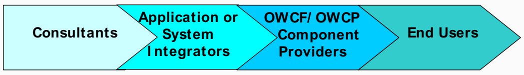
WEARIT @WORK
Thank You!
edna@pasher.co.il
www.pasher.co.il
www.wearitatwork.com
Edna Pasher Ph.D & Associates
Management Consultants

## Exploiting Research Results in Practice

Daniele Tondini/ENEA & Michael Lawo/TZI

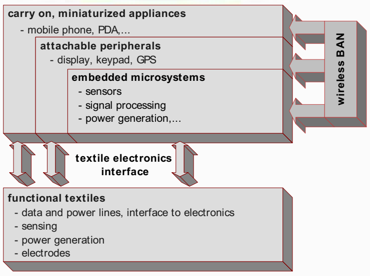
## Research approach, Methodology

- Wearable computing is an innovative technology
- For our 7 applications research was based on standards
  - Open Wearable Computing Platform (OWCP)
  - Open Wearable Computing Framework (OWCF)
- For exploitation we analysed the specific value chain

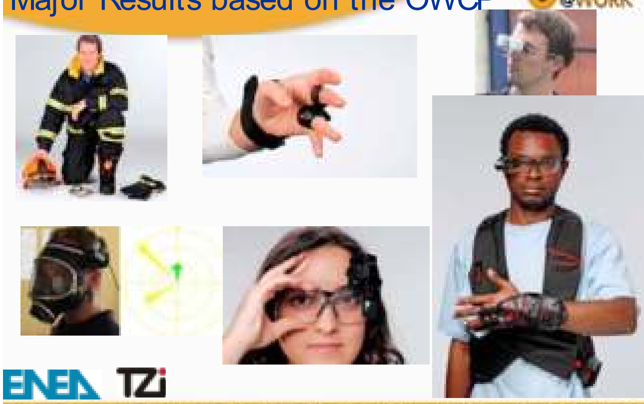



- We developed rules for a corporate model for doing business
- We created a learning cycle that let each single initiative take advantage of benefits coming from the partnership

## Major Results based on the OWCP

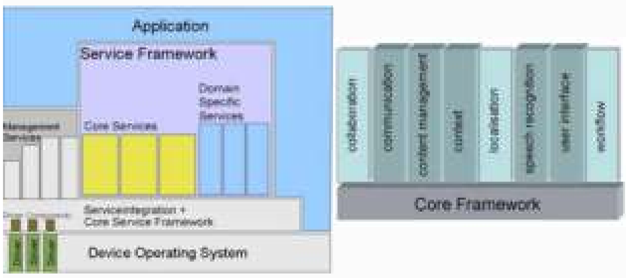



## Major Results based on the OWCP



## Major Results – The LinkVest

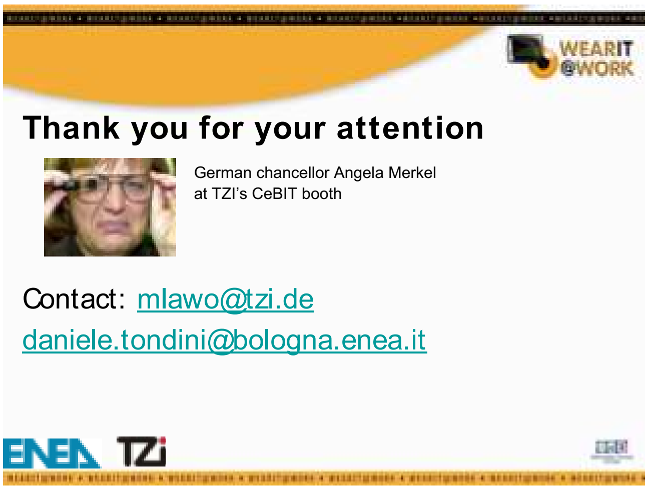
## Major Results based on the OWCF




Major Results based on the OWCF
WEARIT @WORK
Maintenance
Login
Technology Repository with Maturity Levels
ENEA TZi


Major Results based on the OWCF
WEARIT @WORK
Wearable Computing Requires Training
ENEA TZi


Conclusion and outlook
WEARIT @WORK
• Wearable computing provides services for new user groups, especially in the professional environment
• Mobile Computing Systems are needed which enable dual-task environments with a primary real-world task
• Mobile Systems are needed which use personal and environmental sensors in order to provide assistance functions on the move
• Wearable technology has the long-term potential to change the out-of-office workplace just as much as personal computers changed the office environment
• The value chain, the business support group and the business rules will strengthen the field
• The forthcoming 12 months are dedicated to extensive exploitation activities
ENEA TZi


WEARIT @WORK
Thank you for your attention
German chancellor Angela Merkel
at TZI's CeBIT booth
Contact: mlawo@tzi.de
daniele.tondini@bologna.enea.it
ENEA TZi