Paper

Empowering the mobile worker by wearable computing – wearIT@work

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

Abstract— Currently wearable computing is still a technology of niches and in a laboratory stage. With wearIT@work a project dedicated to applications was launched by the European Commission (EC IP 004216). The first year of the project is nearly over and first results were achieved. In this paper the concept of the project is introduced and first results are presented. As the project strongly follows a user centred design approach much effort was put on first investigations with users in the four application domains of maintenance, production, hospital and fire fighting. Beside this results concerning a wearable computing hardware platform and software framework were achieved.

Keywords— wearable computing, applications, user centred design.

1. Introduction

The European Commission set up an *Integrated Project* wearIT@work [1] to investigate wearable computing as a technology dealing with computer systems integrated in clothing. The project has 36 partners, among them EADS, HP, Microsoft, SAP, Sony, Siemens, and Zeiss. With a project volume of 23.7 million € and a funding of 14.6 million € under contract no. 004216, wearIT@work is the largest project world-wide in wearable computing. The TZI – Mobile Research Center of the University of Bremen coordinates the project.

The project wearIT@work contributes to the shaping of today's most challenging computer applications. The intention of wearIT@work is to prove the applicability of computer systems integrated to clothes, the so-called wearables, in various industrial environments. These novel computer systems support their users or groups of users in an unobtrusive way wearing them as a computer-belt. This allows them to perform their primary task without distracting their attention enabling computer applications in novel fields. Interaction with wearables by the user is minimal to realize optimal system behaviour. For this reason a wearable computer has to recognize by integrated sensors the current work progress of a user. Based on the work context detected the system has to push useful information to its user, e.g., how to proceed with the work. Apart from speech output, media could be optical systems presenting the information, e.g., via semi-transparent glasses within the worker's visual field. Output devices for tactile feedback are also applicable.

One of the major goals of the project is to investigate the user acceptance of wearables. Suitable methods for user interaction and processes suited to wearables in industry are identified. Investigations show that methods to detect the work context and a general architecture of wearables as well as a hardware and software platform for the implementation of wearables are urgently needed. Four industrial pilot applications, namely emergency, variant production, maintenance, and the clinical pathway drive the project.

The focus of the emergency activity field is the collaborative planning and interaction using wearable devices. In variant production the challenge is the information integration and the intelligent information presentation. The maintenance scenario has its focal point on context detection and intelligent manuals. For the clinical pathway the focus is on intelligent information logistics and context aware collaboration.

The *Integrated Project* is organized in activity lines (AL) and activity fields to manage its complex structure and follows a user centred design (UCD) approach (Fig. 1). Applications are developed in cycles of 18 months duration each.

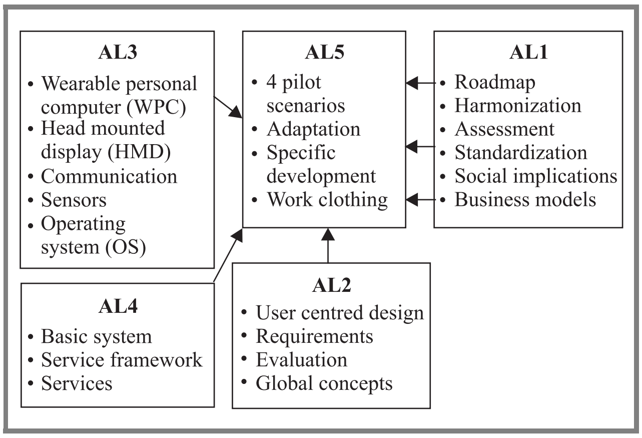

Fig. 1. Organization of wearIT@work.

The partners of the project go for the following advantages. First of all, an improved productivity and flexibility of workers shall be reached. Second, an increased safety at work and a decreased pressure towards automation is aimed at. Third, a simplified access to enterprise information, and fourth, faster group decisions are intended. Last but not least, new information technology products will be introduced into the market based on the pilot applications developed within the project.

"*The worldwide market for wearable computers generated over $70 million in supplier revenues in 2001. The market will increase at a compound annual growth rate (CAGR) of over 51% through 2006, and grow to over $563 million*" [1].

Despite its massive growth, the market for wearables is still a niche market compared to the industrial use of desktop computers. Drivers of a stronger growth will be more standardized hardware and software platforms enabling the new work paradigms.

2. Relation to existing theories and work

There are different approaches to defining wearable computing depending on the research direction and the application domain. In the wearIT@work project the interaction between the user, the system and the environment is focused on. In conventional mobile systems the interaction is based on a modified version of a desktop human computer interface (HCI) and follows the pattern shown in Fig. 2a.

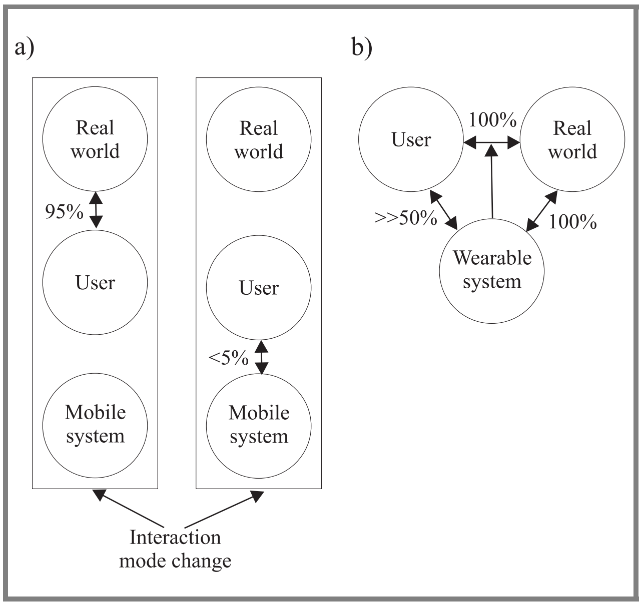

Fig. 2. Interaction between the user, the system and the environment in a conventional mobile system (a) and a wearable system (b).

To operate the system, the user needs to focus on the interface. This catches his attention as well as his physical activity, in particular the use of his hands. As a consequence he/she can either interact with the system or with the environment, however not with both of them at the same time.

Thus to access data on a personal digital assistant (PDA) the user must interrupt whatever he is doing, take the PDA out of his pocket and focus on the device. This mode of operation implies that the range of applications and situations in which the system is useful is severely restricted.

In general, over a course of a day, mobile devices are actually useful at most between 1% and 5% of the time. In addition, many of today's devices are bulky and obtrusive which means that for many activities the user does not even take them along.

In contrast, wearable systems are designed to be permanently useful and usable in a wide range of mobile settings. The corresponding interaction concept is illustrated in Fig. 2b. It allows the user to simultaneously interact with the system and the environment. In addition, there is direct interaction between the system and the environment as well as the possibility of the system mediating the interaction between the user and the environment.

The implementation of the wearable interaction concepts involves four main issues:

1. The system must be able to interact with the environment through an array of different sensors distributed in different parts of the outfit. In particular it must be able to develop a certain degree of awareness of the user activity, his physiological and emotional state, and the situation around him. This is often referred to as **context awareness**.

2. The user interface needs to be operated with minimal cognitive effort and with no or little involvement of the hands. In general, the low cognitive load is achieved through appropriate use of the context information. Thus for example instead of having the user select a function from a complex hierarchy of menus, the system should derive the two most likely options from the context information and present the user with a simple binary choice. In terms of the actual input modality, simple, natural methods such as nod of the head, a simple gesture, or spoken commands are preferred.

3. Using context information the system should be able to perform a wide range of tasks without any user interaction at all. This includes system self-configuration tasks as well as automatic retrieval, delivery, and recording of information that might be relevant to the user in a specific situation. A trivial example of a context-dependent reconfiguration could be a mobile phone that automatically switches off the ringer during a meeting.

4. The system must be seamlessly integrated in the outfit so that it neither interferes with the user's physical activity nor affects his appearance in any unpleasant way. This means that unlike many conventional mobile devices, it can be taken along nearly anywhere.

A trivial example of an existing device that adheres to the above requirements is a modern hearing aid computer. It is unobtrusive, useful during most of the day, requires hardly any cognitive effort to operate, and by definition of its function, mediates the user's perception of the real world. In addition advanced devices are able to automatically adjust the volume between noisy and quiet settings and even optimize the amplification mode to suit the situation such as conversation or a concert.

In wearIT@work we address more advanced wearable systems. They can detect complex activities such as social interaction, or certain specific work related actions (e.g., in maintenance) and use this information to deliver a variety of services exactly tailored to the user needs in a given situation.

3. Research approach

The research is based on the user centred design approach as defined in ISO 13407 [5] (see Fig. 3). Based on scenario definitions and discussions between the stakeholders of the project and the application partners workplace studies were performed on the site of the users to validate the scenarios. In the next steps mock-up prototypes are developed and evaluated again with all stakeholders at the user sites.

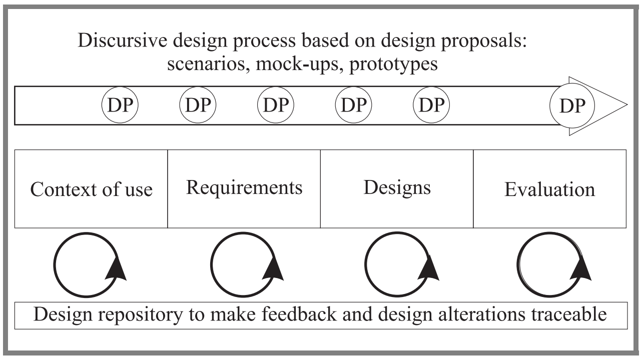

Fig. 3. Generic ISO 13407 compliant UCD process model.

The social computing factors are with wearable computers similar to those of laptops and mobile phones. Assumed wearable computers are provided by the organization to the employees, they might be used beyond normal working hours, beyond the physical borders of the organization, like at home or beyond the organizational work context like for private or public purposes not related to the employee's job. The results of these circumstances are many partially interacting factors as those given in Fig. 4.

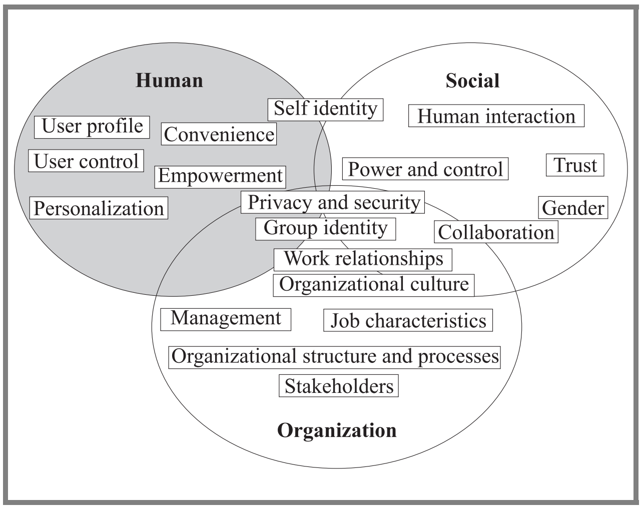

Fig. 4. Social computing factors map.

Aspects like self identity, privacy and security or group identity need a clear understanding and negotiations by the stakeholders for achieving a common understanding of the implications and consequences of the use of a wearable computing technology in a professional environment as addressed in the project.

4. Findings

Beside the application oriented interaction with the end users of the project a lot of effort was put into a common understanding of wearable computing (see above) and first steps towards a common wearable computing platform and framework.

A hardware platform consisting of a core wearable computing unit, input and output devices, general peripherals, and

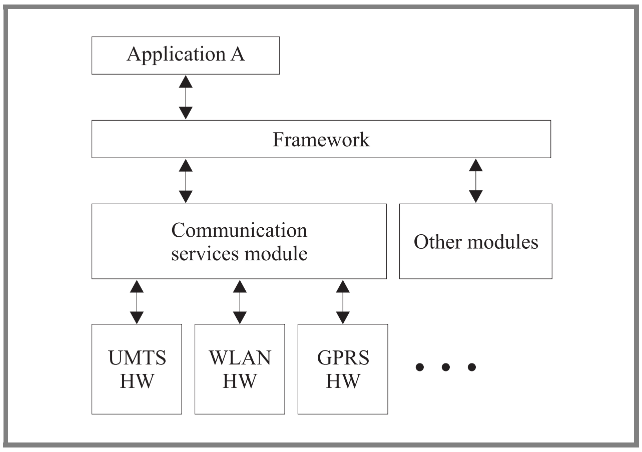

Fig. 5. General wearIT@work architecture.

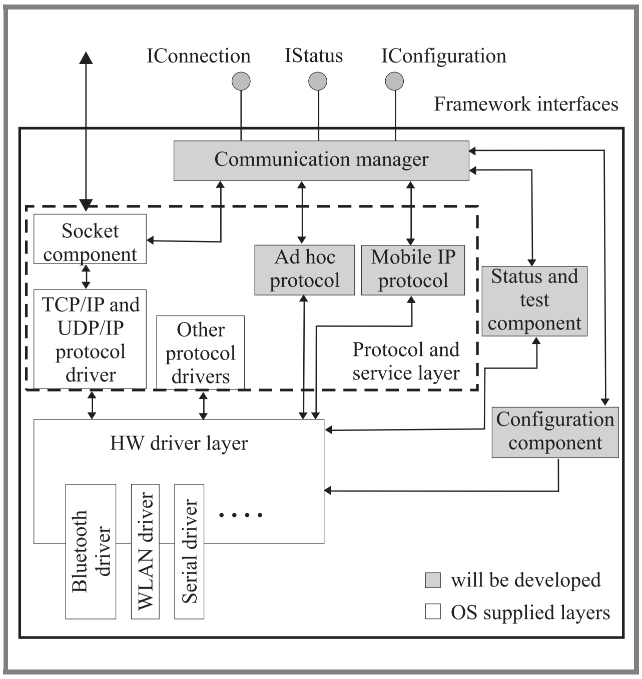

Fig. 6. Communication service module architecture.

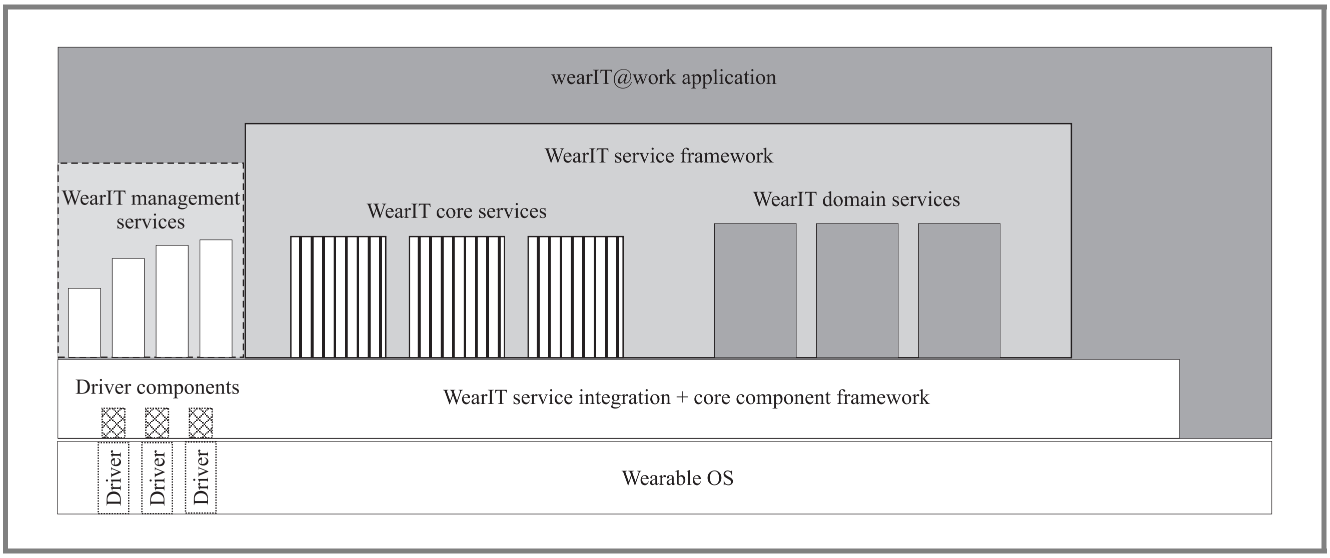

Fig. 7. General structure of the software framework.

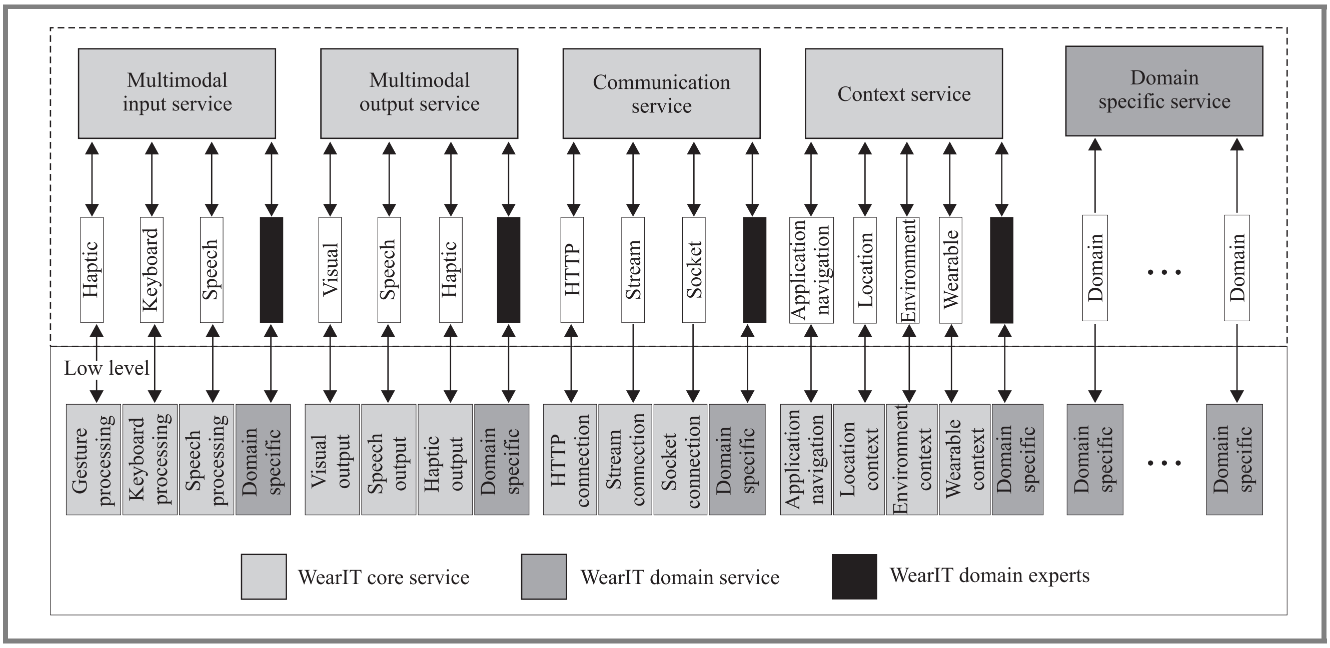

Fig. 8. Service framework.

sensor and communication subsystems was defined. One of the challenges is the necessity to provide the end-user with a seamless access to heterogeneous networks. This reflects the general wearIT@work architecture as shown in Fig. 5 as well as the communication service module architecture as given in Fig. 6.

The idea of creating a common software framework based on a common hardware platform is of great importance from the perspective of the project as well as beyond. Only in the case that wearIT@work will be successful with this process a remarkable impact is achieved for the exploitation of wearable computing solutions. In this case not only the four domains addressed within the project application but also other related application domains will benefit from the result and in the case of the addressed standardization push also the developers of devices, components and solutions will be covered.

The general structure of the software framework covers beside a service registry and high level services also core services like context awareness, communication, I/O, and security (see Fig. 7). Beside these core services domain specific services of the same structure exist. The idea is to integrate services of common use within the application domains of the project into the core services. The advantage of this approach is that with increasing and/or changing requirements the general structure remains valid. Figure 8 illustrates this fact; core and domain services can be made available on different levels.

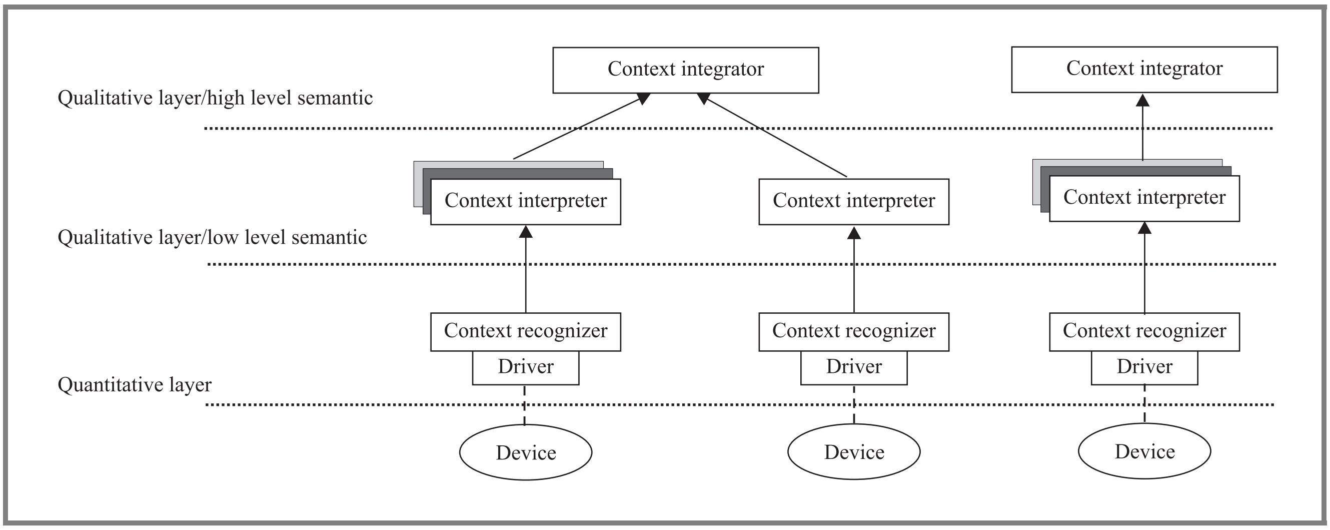

Fig. 9. Context detection using sensors.

Context detection is one of the essential success factors of wearable computing as mentioned above. Only in the case of using sensors a context can be detected with high reliability, and the cognitive load of the end-user can be managed in a successful way. This is considered to be one of the most scientifically challenging topics of the project. Other challenges like the robustness required always outside the lab in the real world are more relevant for producers and developers of devices.

To master the context detection problem, a general approach was discussed which is suitable for extension and adaptation (see Fig. 9). It is foreseen to perform series of tests with the end-users using existing sensor subsystems that are still basically in a prototype stage. These end-user tests are necessary to decide which further research and development work on sensor subsystems is necessary to achieve the performance accepted by the end-users.

5. Conclusion

In this paper the results of the first nine months of wearIT@work were presented. There are still nearly four years of research to be done and there are still many results to be achieved, but the fundamental steps towards a user centred design approach, a hardware framework and software platform are done. With the creation of the Open Wearable Computing Group [3] and the International Forum on Applied Wearable Computing [4] organized annually, a community building process in industry and science has been initiated. It is the intention of the project and the accompanying activities to understand the project as the leverage for wearable computing, even if miniaturization and low power computing devices as well as ubiquitous wireless communication are still in an emerging stage to provide the wide spectrum of innovative solutions which is necessary to achieve wearable computing anytime, at any place, and in any situation.

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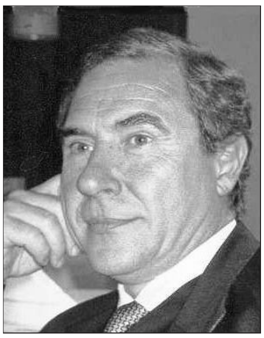
Michael Boronowsky is Managing Director of the Center for Computing Technologies (TZI), University of Bremen, Germany. In 1992 he had finished his studies in electrical engineering at University of Applied Science Aachen. After which he worked in a measurement device company as leading development engineer. He went back to university and studied computer science in Nijmegen, Netherlands, and received a Master in computer science in 1995. Since this time he is working at

the University of Bremen. In the beginning he was working in the area of artificial intelligence research. He developed machine learning algorithms, to learn qualitative physical models from the observation of measurement data. In his Ph.D. he focussed on methods for the automatic interpretation of time series data based on decision tree induction. In 1999 he became responsible in co-ordinating the wearable computing research at the TZI. He finished his Ph.D. in 2001 and became Managing Director of the Intelligent Systems Department. Since 2002 he is Managing Director of the TZI. He coordinated the application of the IP-proposal "wearIT@work – empowering the mobile worker with wearable computing" featuring a groundbreaking vision of the computer empowered knowledge worker of the future. Doctor Boronowsky is Vice Chair of the European Community "mobility@work" and also Vice Chair of the overall AMI@work community focusing on the economical breakthrough of the ambient intelligence vision for the mobile worker. Beside his management activities he is still working as senior scientist in research projects related to mobile computing and is supervisor of several master thesis in this area.
e-mail: mb@tzi.de
Center for Computing Technologies (TZI)
University of Bremen
P.O. Box: 33 04 40
D-28334 Bremen, Germany

Peter Knackfuß was born in 1955 in Munich. After school he went to Fachhochschule Munich and to University of Munich, where he left 1984 with German Diplom degrees in mechanical engineering and in electrical engineering. Then he joined Gesellschaft für Reaktorsicherheit in Munich working as a software engineer. In 1987 he changed to the Bremen Institute for Industrial Engineering and Work Science – BIBA starting as a research engineer and working as a department leader later on. In parallel he wrote Ph.D. thesis at University in Bremen and was graduated as a doctor engineer in 1992. In 1997 he left BIBA and founded his own company dealing with network technology and with support of industry and governments to enter European funding schemes. Doctor Knackfuß has continuously performed work in more than 15 European projects as a researcher since 1984 and has till now managed about 10 European research projects in different European funding programmes.
e-mail: Peter.Knackfuss@infoconsult.nu
Info Consult GmbH
University Avenue 17
28359 Bremen, Germany

Otthein Herzog holds a chair in artificial intelligence in the Department of Mathematics and Computer Science at the University of Bremen, Germany. He directs the TZI – Center for Computing Technologies, the Collaborative Research Center 637 – Cooperating Autonomous Logistics Processes sponsored by the Deutsche Forschungsgemeinschaft, and the Mobile Research Center in the Mobile Solution Center Bremen. His current research interests include wearable and mobile computing, multi-agent systems, semantic data transformation and mediation, content-based analysis and retrieval methods for digital libraries, and digital image processing. Before Doctor Herzog joined the University of Bremen, he worked for IBM in various R&D and managerial positions for 16 years. Professor Herzog has co-authored and co-edited seventeen books and more than 80 scientific papers. He is a member of Gesellschaft für Informatik, DAGM, ACM, and the IEEE Computer Society.
e-mail: herzog@tzi.de
Center for Computing Technologies (TZI)
University of Bremen
P.O. Box: 33 04 40
D-28334 Bremen, Germany



Michael Lawo is with Center for Computing Technologies (TZI) at the University of Bremen since 2004 as the Technical Manager of the IP 2004-004216 wearIT@work after being the CEO of a group of SME in the IT domain since 1999; from 1996 to 2000 he was CEO of an IT consulting firm which now belongs to UNILOG S.A./Paris and from 1991 to 1995 top manager information systems with the Bremer Vulkan group. He was consultant before joining the nuclear research centre in Karlsruhe from 1987 to 1991 as head of the industrial robotics department. He is a 1975 graduate of structural engineering of Ruhr Universität Bochum, received his Ph.D. from Universität Essen in 1981 and became Professor in structural optimization there in 1992. In 2000 he was appointed as Professor of honour of the Harbin/China College of Administration & Management. He is author, co-author and co-publisher of five books and more than 110 papers on numerical methods and computer applications, optimization, IT-security and wearable computing.
e-mail: mlawo@tzi.de
Center for Computing Technologies (TZI)
University of Bremen
P.O. Box: 33 04 40
D-28334 Bremen, Germany