Tele-monitoring as a medical application of Ubiquitous Computing

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Abstract: In this paper we present why tele-monitoring is a promising application domain for Ubiquitous Computing. We discuss how the characteristics of ubiquitous information systems can be applied in the design of tele-monitoring applications and what special conditions and problems have to be regarded. Finally, we present the results of the implementation of such an application realized in a joint research project.

1. Introduction

Ubiquitous Computing (UC) [Wei91] deals with future scenarios of information technology utilization. It considers computing environments, where the user is surrounded by a large amount of application-specific, networking information appliances. In order to improve user friendliness, ubiquitous computing systems have to be unobtrusively embedded into their environment[16].
A common problem of UC-research, is the transfer of the theoretical concepts into usable applications. Challenges remain in deploying Ubiquitous Computing System, like technical complexity, privacy and security. Problems also arise with respect to economic factors when developing UC products. According to [DaGe02], we are still many years from creating "real" ubiquitous systems deployed to the extend that they become an integrated part of our everyday lives. There is, however, at present significant potential in integrating and applying UC techniques to medical applications such as "health monitoring". The UC techniques listed below, highlight the distinct medical advantages and high potential for cost savings when theory is applied effectively:

- Patient mobility is maximized by physically embedding the devices into distributed wearable or implantable systems

- Networking allows the ubiqutious provision of high performance services, such as pattern recognition with neural networks. Thus, decentralization is compensated.

[16] The following two terms: "the disappearing computer" and "augmented reality" are often used in this context

- A better usability is achieved through context-aware, cognitive-embedded systems. This is essential for the use in a home-monitoring scenario (where devices adapt themselves to the user and not vice-versa).

In this paper we discuss the key technologies and the challenges that exist with the application of UC in tele-monitoring systems.

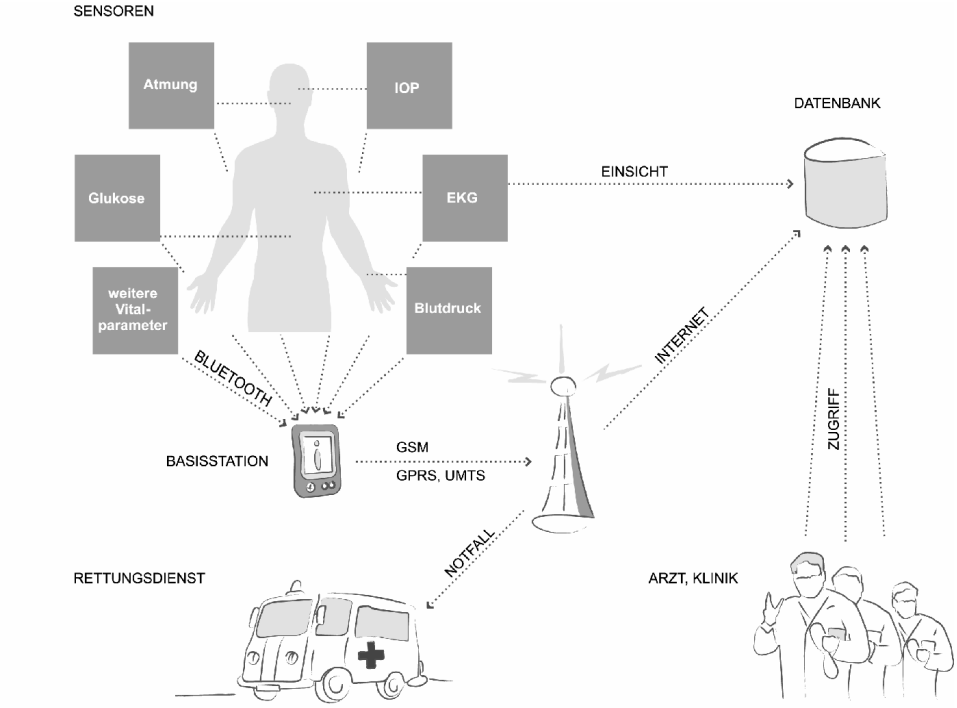

Figure 1: system concept for the PHMon project

2. Materials und methods

We tried to apply the concepts of ubiquitous computing systems (cognitive and physical embedded systems, ad-hoc networking and spontaneous interoperation, integration in a global information base, context-awareness) with the development of a home-monitoring system as part of the PHMon research project (see figure 1) [KSM02]. Therefore, special requirements of mobile vital monitoring applications have to be considered. These include:

- Miniaturization and low power consumption to ensure mobility
- Intuitive, context-aware user-interfaces to enable usability for diseased and elderly people

- Special security requirements to preserve privacy due to the sensibility of patient data

A reliable home-monitoring system fulfilling the requirements mentioned above can only be achieved using a combination of the latest technologies. In the following section we explain key technologies considered in this work.

2.1 Micro-technical smart sensors

Today, many vital signs can barely be collected with wearable sensors. Therefore, new measurement principles allowing a micro-technical implementation have to be developed. Micro-technical sensors have several advantages: They enable high integration with low power consumption, and thus high patient mobility. The cost-effective realisation allows the product to be manufactured in mass numbers.

2.2 Mobile & Wearable Computing

Personalized mobile information systems can be developed with high usability in mind, if they are especially adapted to an application with custom hardware and software functions, like for example in logistics information systems. This also applies to mobile health-monitoring applications. To fulfil requirements concerning reliability and security, certain adaptations have to be implemented [Stan02]. Attention must also be turned on easy handling of the system to avoid mistakes being committed by the patient. Since mobile information devices are subject to very short product life-cycles, a device-independent software design is very important for the development of such mobile computing applications.At ITIV we are testing different mobile computing platforms (Linux, Symbian OS, JAVA MIDP) for their suitability for health-monitoring applications. We are using handheld devices acting as the “personal health assistant” as the mobile base-station in the PHMon-project.

2.3 Wireless Communications (especially Bluetooth and GSM/UMTS)

The widespread availability of wireless cellular networks provides a basis for mobile telemetry applications. The new packet-oriented cellular phone standards (GPRS, UMTS) are charged in a pay-per-volume model. Thus, a monitoring device can always be connected without generating high costs, because the data transfer rates are very low in vital-monitoring applications compared to e.g. multimedia transmissions. Future cellular network systems will also provide enhanced localization possibilities (e.g. E-OTD, OTDOA, A-GPS). This is very important for emergency localization in patient monitoring applications.

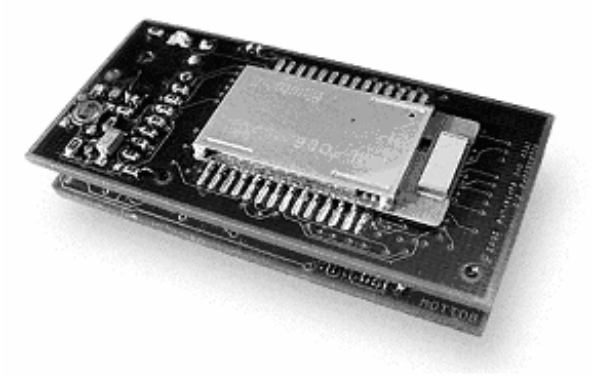

Figure 2: Prototype of an ECG-Sensor with Bluetooth-Interface

Several technologies can be taken into account for body area and personal area networking (BAN/PAN). Wired connection should only be used if they are not restricting the patient's mobility, like in smart clothes with embedded components and wires. We are preferring Bluetooth as wireless communication technology because of its ad-hoc-networking abilities and its extensive integrated functionality, such as service discovery, power management, encryption and authentification.
Besides from ad-hoc networking technologies, an automatic vital-monitoring also requires powerful open communication protocols enabling spontaneous interoperability between different medical information systems.

2.4 Web-based Electronic Patient Record (EPR)

In order to reduce the costs of public health systems using home-monitoring technology, the collected vital data must be automatically shared with the heterogeneous information systems (for example clinical information systems). This is difficult due to a lack of set application-level communication standards. This situation can only be changed by a broad cooperation of the concerned institutions and system developers. An approach to overcome this problem is to use a patient-centred web-based EPR system, so that information can be easily accessed through a secure internet connection.

3. Results

A demonstrator has been developed to evaluate the concepts of the personal health monitoring system. It consists of wearable and external sensors with integrated signal processing and communication abilities, where a PDA acts as mobile base station and a Bluetooth-enabled mobile phone allows for Internet connections. The Internet connection is used to directly transmit the measured vital signs into a web-based EPR. For a first scenario, we used a wearable multi-channel ECG-sensor and a weight scale as well as a blood-pressure monitoring device as external sensors. This setup may be used for the monitoring of patients suffering from cardiovascular disease, where the regular

measurement of the vital signs enables a better control of the therapy and early recognition of complications. All the sensors were equipped with a Bluetooth-Interface for wireless transmission of the vital-signs to the PDA. To minimize manual Bluetooth configuration effort, we developed a special self-configurating application protocol with integrated connection and security management functions.

Figure 2: Telemonitoring-application based on Bluetooth-Communication

Over the next few years, most of the mobile phones will likely be programmable and have an integrated Bluetooth-Interface. Since most of the patients in industrial countries possess a mobile phone, the realization of flexible tele-monitoring applications such as the one described in this paper will be much more competitive than today. Future systems will only consist of appropriate sensors with communication abilities and software components for personal mobile devices.
Sensor manufacturers can easily integrate their products into such a telematic platform. To facilitate this task, we developed hard- and software components enabling the integration of the necessary communication abilities in existent systems. Using these components, we plan to adapt several available sensors, such as those used for glucose monitoring, tonometry, body temperature measurement, and more, to our platform in order to build an array of sensors for the diagnosis and monitoring of different diseases.

4. Discussion

Using this system prototype we want to evaluate the concepts of ubiquitous computing (embedding, networking, context-awareness) in patient-monitoring applications. Future work will focus on the development of powerful self-configuration application protocols for spontaneous interoperation, on context-aware user interfaces and also on further integration of the systems. The latter includes miniaturization of ubiquitous sensors and integration of such medical sensor into everyday objects and smart clothes.
In the next few months we will start a study of our tele-monitoring system. In this study, we will evaluate the home-monitoring of heart-failure patients in order to gain experience on the practical use of the system.
Besides from tele-monitoring of high-risk patients the system may also be used in elderly-care applications, where for example a sudden fall sensor con be combined with and an emergency button and a location system.

References

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