Rapid Prototyping for Ubiquitous Computing in Health Care Real Life Settings

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Existing software systems in hospitals, including Electronic Patient Records (EPR) in Hospital Information Systems (HIS), reduce double documentation, provide parallel access to information and guarantee up-to-date records. However, in hospitals clinicians constantly move around between different work places and need to have fast access to relevant information. Classical solutions, which are bound to a specific office or place where it is necessary to login and waste valuable time in order to find relevant information, are insufficient for enhanced clinical applications. It is obvious that ubiquitous computing devices, including RFID, have an enormous potential for the improvement of manifold workflows within a Hospital. The authors developed prototypes with the aim of raising awareness and to gain insight into clinical workflows and tested their prototypes in real-life clinical settings within Graz University Hospital – which is amongst the largest in Europe.

Introducing Statement: *“The purpose of computing is insight, not numbers.” (Hamming, 1962)*

1. Introduction

Work in hospitals is formed by many cooperating clinicians having a high degree of mobility and parallel activities and usually not having a classical office workplace [1], [2]. Due to our long-term experience in Hospital Information Systems we can emphasize that existing software solutions do often *not* consider this issue. As a result our research addresses existing problems, such as immobility, inefficient user interfaces and navigation or misidentification, using the approach of Ubiquitous Computing (UC) – which, in the classical sense of Mark Weiser, enhances the use of computers by making many computers available throughout the physical environment, whilst making them effectively invisible to end-users [3].

Consequently, our research focuses not only on technological, but on User-Centered feasibility research and the development of Ubiquitous Computing demonstrators, taking social issues of real work requirements and consequences into consideration. This combination makes it possible to assist enhancing applications with the idea of UC to reduce problems and generate new improvement potential in Health Care. Published research work describes improvements and existing infrastructure of Ubiquitous Computing in hospitals [4], [5]. However, most of this infrastructure has been extensively tested in the labs but is *not deployed in hospitals* [6]. One exception we found to date is the approach of SIEMENS in the Jacobi Medical Center in New York (see http://www.sbs-usa.siemens.com/press/docs/jacobimedical-casestudy.pdf). Similar to that approach, we did our customized and User-Centered Development within Graz University Hospital, which is amongst the largest hospitals in Europe.

Our current research concentrates on optimizing processes in the field of hospitals by introduction of RFID, which obviously is a good representative of UC [7]. The basic technology we use is RFID (Radio Frequency Identification) *in combination* with communication technologies including Bluetooth and WLAN. We focus on 13.56 MHz HF RFID technology with DoT (Data on Tag). We use 13.56 MHz HF technology because we do not need a large range of signals, such as the UHF technology offers, and we are able to provide offline capability of data with 13.56 MHz tags.

We use PCs for lab settings but Tablet-PC’s and Handhelds (PDAs) with RFID readers connected for real life settings. For storing data on the chip we abstract a data model for storage on the chip. Using this method, we can model and define a suitable data model for each scenario in hospital work.

Our RFID middleware, which aggregates and filters RFID events, is based on Microsoft .NET and we have it implemented as a windows service. To provide inter-operability for clients of all platforms and third party business applications we used a HTTP/SOAP Web service interface for communication.

2. Rapid Prototyping and User-Centered Development

It is a generally known fact that many software developers rarely use Usability Engineering Methods (UEM) on software development projects in their work and it is seldom that projects adopt a fully integrated User-Centered Development (UCD) approach in one strategic shift. This includes early focus on the end user, empirical studies and iterative development of prototypes. In this project we involved the end-users early in the design and applied a range of Usability Engineering Methods [8], which perfectly fit together with rapid prototyping techniques [9]. Although UCD is not a clearly concrete methodology, there are some common principles which proved to be essential for the success of this project:

- Understanding of the work of end-users and systematic analysis of their tasks;
- Involvement of the users from the beginning in the project life cycle;
- Setting of simple and measurable goals;
- Evaluation and subsequent iteration.

3. Research Prototype

3.1. Hardware

During our phases of experiments (input-workshops, real-life setting, see details in section 4) we used different hardware (figure 1):

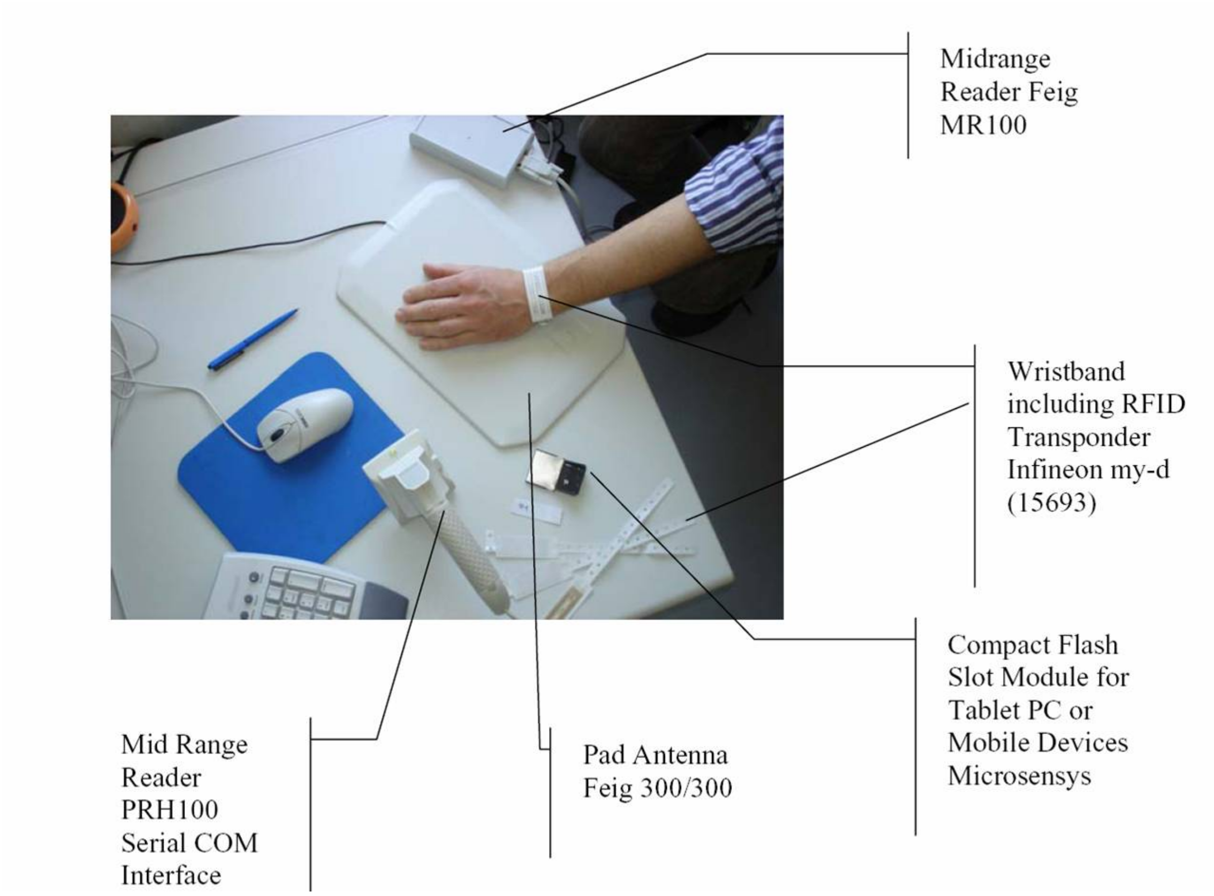

Figure 1: Devices used during our first experiments

3.2. Software

The software we developed for our experiments is based on You-R® OPEN software suite v2.1 which behaves as an RFID middleware that aggregates, filters and collects data generated by RFID readers. Data collected by the reader via air interface is made available to our *MedID Interface Layer* by an event based model (see figure 2). Each time a RFID wristband responds to the reader a *TagAdded* event is fired by the reader device in RFID middleware. The same mechanism is used when a write command is sent to the wristband. After processing the write command RFID middleware generates events, which report if writing succeeded or failed *(TagWriteSucceeded rep. TagWriteFailed).*

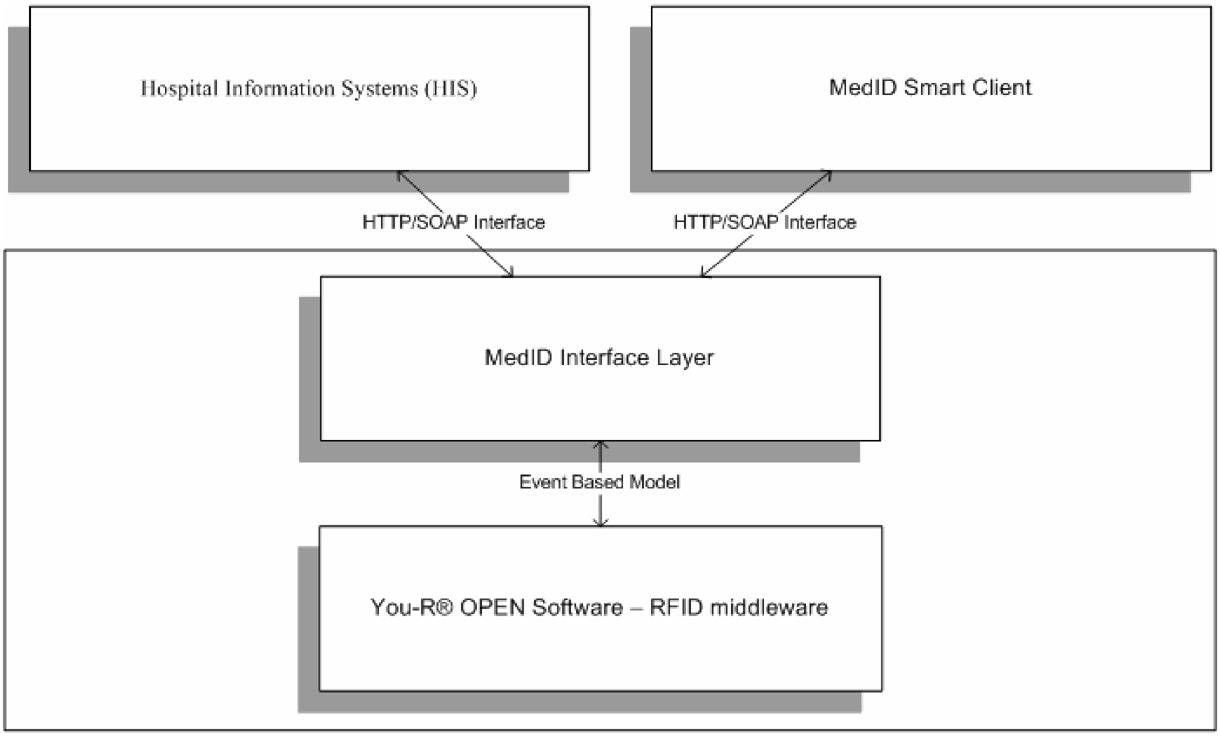

Figure 2 The software architecture

Our *MedID Interface Layer* subscribes to relevant events of RFID middleware during initialization and is implemented by an extension of the framework via a HTTP/SOAP Web service interface. This interface provides external application and systems, exactly those methods that are required for different scenarios in the hospital workflows. The Interface is constructed as a facade to hide the internal structure of the complex RFID system [10]. The RFID middleware and the *MedID Interface Layer* are capable of running on Windows desktop systems, PDAs and handhelds with Windows CE or Pocket PC and on Tablet PC running the Windows Tablet PC Edition.

To exemplify, we implemented the so called *MedID Smart Client* that uses the provided web services of *MedID Interface Layer*. HTTP/SOAP Web service technology enables platform independent communication without intimate knowledge of legacy systems such as the existing HIS.

MedID Smart Client, in our case, calls subscription methods for relevant RFID events and sends the location to be notified when the corresponding event occurs.

To enable this bi-directional communication via Web Services, the *MedID Smart Client* also has an integrated Web Server that provides web services to *MedID Interface Layer* for notification.

4. Experimental Setting

4.1. Input-Workshops

At first, the ability of the prototypes has been demonstrated during so called input-workshops together with medical doctors, Nurses and the responsible people in charge of the HIS. After gaining insight into possible problem areas, the most interesting workflows were examined in real-life scenarios.

4.2. Real-Life Scenarios

4.2.1. Patient Check-In

When patients check in at hospital, an RFID tag is added to the ordinary wristband. Information regarding the patient is entered by an application at check in and security uncritical but important information such as name, blood type etc. is stored on the RFID tag. Because of the unique identification, the patient wearing his wristband is always assignable to his electronic patient record. In the case of online (WLAN) availability, historical data and actual results can be easily retrieved by identifying the patient by a reader and retrieving information from the central electronic patient records. In addition, this system provides positive patient identification and information of essential data of the patient even if the network is broken down. For data security reasons, critical information is not stored on the tag but is easily retrievable from the central electronic patient records due to the automatic identification of the patient.

Patients check in at the Hospital – in addition to an ordinary wristband – an RFID transponder is supplied (figure 3).

Figure 3: Inside the standard wristband an RFID tag (right) is added

Patient data is entered via our application at the check-in-point (figure 4), any previous patient data can be retrieved from the HIS. From this information, uncritical but important data (such as name, blood type, allergies, vital medication etc.) is transferred to the wristband's RFID transponder. However, concerning the actual security of the data we must perform some more research [11]. The Electronic Patient Record (EPR) is created and stored at the central server. From this point in time, the patient is easily and unmistakably identifiable. All information can be read from the wristband's transponder or can be easily retrieved from the EPR by using a reader to identify the patient. In contrast to manual identification, automatic processes are less error-prone. Unlike barcodes, RFID transponders can be read without line of sight, through the human body and most other materials. This enables physicians and nurses to retrieve, verify and modify information in the Hospital accurately and instantly. In addition, this system provides patient identification and patient data – even when the network is unavailable.

Figure 4: Input of Data at the patient check-in

4.2.2. Doctors Ward Round

Physicians are equipped with Tablet PCs (figure 5) that have an RFID reader plugged in via PCMCIA (Personal Computer Memory Card International Association) during their ward round. When they get nearer to a patient's bed, they identify the patient by the RFID wristband with the reader attached to the tablet PC. Immediately the patient and the physician – for access security reasons - is identified, the system requests all relevant information from the patient's record and displays this information in the "ward round application". With a special pen the physician is able to enter notes and modify or add medical data. Afterwards, this information is transferred to the central data storage of the patient records.

Figure 5: The mobile solution by using a Tablet-PC

4.3. Identification of Patient

On multiple I-points (Identification Points) in our hospital, a patient can be easily identified and relevant information can be read from the tag or retrieved from the EPR which is stored in the HIS. Therefore, industrial handhelds (figure 6 left side) as well as common (figure 6 right side) can be used. In contrast to manual identification, many processes can be carried out automatically and are less error-prone. Unlike barcodes, RFID tags can be read without line of sight and through human body, or other materials and other objects.

This enables physicians and nurses to accurately and instantly capture, verify and modify medical information in hospitals with higher quality.

Figure 6: Industrial Handhelds (left) but also common PDAs (right) – which are widely available amongst medical doctors – can be used during the ward round

5. Conclusion

It is essential to have working prototypes at hand as early as possible to demonstrate the possibilities and raise awareness amongst the end users and amongst the executives, regarding the medical director and hospital information system. During rapid prototyping, User Centered Development proved to be efficient. This method of involving the end users from the beginning proved to be very helpful for the further development. Based on input from the end-users, the prototype can be adapted, iterated and reconfigured. Finally the prototype has to be tested in various real-life settings. This project showed clearly the potential of RFID applications to improve workflows aiming at providing clear benefits for the end users.

6. About the Authors

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