Wearable Computers in Clinical Ward Rounds

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Abstract

Today's hospitals are under an increased pressure to become more efficient. There is an increasing number of patients and less budget for treatment. Hospital information systems promise such a necessary increase in productivity. However the medical point of care is different from any traditional office workplace. Usability is of utmost importance because the primary concern of doctors and nurses is the patient and not the information system. In this paper we show how wearable computing can be utilized to achieve a usable solution for the point of care. A user-centered design process is followed to achieve the necessary usability. The remainder of this paper describes our solution and the expected benefits as well as the two most important steps of our design process.

Introduction

Currently a great deal of effort is made to "electronify" the entire paperwork in hospitals. This trend is not just reinforced by the prospective cost savings. By virtue of the demographic development, there are increasing numbers of patients and a strong demand for better services in the publicly funded healthcare sector. However, this means that the clinical staff needs to enter all the relevant information into a computer system. But the clinical workplace is not comparable to a normal office workplace [2,4]. The clinical staff needs to be mobile while frequently performing tasks in the real world that interfere with normal computer usage. In addition to the insight that usability is one of the key factors for a successful introduction of computer systems in hospitals [5], it is clear that new modes of interaction are necessary in order to support the electronification of documents [2].

Combining wearable technology with pervasive computing devices, such as sensors or actuators, is an approach with high potential for being an important part of IT solutions for applications in hospital environments [1,2,6]. Wearable technology promises advantages such as hands-free operation and context-aware user interfaces. The obtrusiveness present in today's desktop applications, which demands the full user attention, can be minimized through wearable computers by using novel interaction techniques that better coexist with the clinical work. Moreover, such systems have the potential to change and streamline existing workflows. We have explored these possibilities in a case study following a strict user-centered design (UCD) process to ensure the acceptance by the medical staff.

Our research is focused on the Austrian public healthcare sector as part of the wearIT@work project. wearIT@work is a European Union funded project running under the auspices of Framework Program 6, involving 36 partners from across Europe. The project aims at moving wearable computing from the research

laboratories into real world applications. Four strategic industrial sectors were selected to work as pilot scenarios in order to prove the applicability of the project's results. Healthcare is one of these industrial sectors. Our partner in this sector is gespag, a group of hospitals in Austria. The studies discussed in this paper have taken place in one of their hospitals.

In the project's first phase, we dealt with understanding the problems and challenges within the application domains. In the healthcare domain, we started with on-site visits in the hospital, observing the users while performing their work and doing interviews with people from several departments. These initial studies confirmed the importance of having computer support at the point of care [3,8]. The following section contains a detailed description of the scenario chosen for deeper analysis. Then we describe how this scenario can benefit from a wearable solution. After that we detail two specific steps we have undertaken in our UCD process, a mock-up study and the design of a prototype solution. We conclude the paper with some remarks on the work performed and an outlook on future work.

The Ward Round Scenario

The main focus of our studies is an important scenario in hospital and healthcare activities, namely the daily ward round. Here, cooperation between the involved actors is imperative. The ward round is the central element of clinical healthcare and mostly the only occasion when the treating doctor actually sees his patients. Furthermore, most of the important decisions about the patient's future treatment are made. Examinations and laboratory analyses are organized, and medications are prescribed. The activities are performed collaboratively by the responsible physician and at least one nurse. However, the actual workflow is heavily dependent on individual styles and work practices. Considering different countries, hospitals and even doctors, there are large differences how the ward round is organized.

Current work flow and collaboration process

Before the ward round, the nurses make sure that all relevant patient documents are correctly sorted into the files in the document-cart, including any new findings, which have to be printed out on paper. During the ward round several basic tasks need to be performed by the visiting team of doctor and nurses: getting information about the patient's current status, interacting with the patient (talking, examinations) and making decisions about the further treatment. The large cart containing all the ward's patient files is the source of almost all information about the patients. The patient files contain all relevant documents including x-ray pictures and laboratory results as well as examination reports. When the doctor approaches a specific patient, he needs to get an overview of his current status. If the patient is unknown, the visiting physician needs to browse through the whole file to get the picture of his condition. When the patient is already known, it is sufficient to read the latest reports and findings.

New information created during the ward round, for example the data needed for the organization of future examinations, is dictated by the doctor while a nurse takes handwritten notes. After the ward round is finished, a large part of the handwritten data is entered into the computer system. This activity takes place at the ward station, and is performed by a nurse. However, information like the examination question for an x-ray examination must be entered by a doctor that is qualified for that kind of activity.

Problems with the current process
The current work and collaboration process can be improved concerning several issues - the most important ones being activity performance time and accuracy of information.

In terms of *time*, the ward round itself, i.e. the actual visit with the patients and the connected diagnosing and organization of future treatment, is already heavily optimized towards the time spent by the doctor. However, the pre- and post-processing work of entering data into the computer system requires a considerable amount of resources. The pre-ward round preparation of the patient files consumes a substantial amount of time. The post-ward round activity of entering handwritten notes into the computer system is another task that requires a considerable amount of resources. This activity is mainly performed by the nurses and takes away time from their core task, which is patient care. Consequently, the quality of care in general is affected. An additional factor that affects the time needed to finish post processing work is the authorization regulation. If the responsible doctor is not available to enter sensitive data into the system himself, the nurses either have to wait until the doctor is available, or they can ask another doctor to do it on his behalf. Then the information can be released. This can take several hours depending on the doctors' schedule, and obviously there is an associated negative effect for the staff in other departments who may need this information in order to prepare activities concerning the patients in question.

In terms of *accuracy* of information entered, the current process is error-prone. First of all, there is no reliable method for identifying the patient. The doctor and the nurse currently rely on the room plan if they don't personally know the patient. They have to trust that the patient lying in the bed is the one actually belonging in the respective bed, which can be a problem with aged patients who might confuse the beds in their room. Secondly, new information is often processed in several steps before it is finally documented in the computer system. The doctor dictates, the nurse takes handwritten notes, and later transfers these into the computer. The potential for misunderstandings and errors due to the human factor is certainly present. Thirdly, authorization regulations potentially have an effect on the accuracy of the entered patient data. In cases where the doctor who performed the ward round does not have the time to enter his own orders into the computer system (this applies for those orders the nurses are not authorized to enter) and another doctor has to take over this task. This doctor may not have taken part in the ward round at all, and only knows what he has been told about the patient and his planned treatment. This may lead to misunderstandings and errors as well. All inaccurately entered information could have more or less severe consequences. For example, if the wrong examination is ordered and performed, important information about the patient's *real* condition is delayed, possibly leading to severe consequences for his health.

Benefits of a Wearable Technology Solution

By introducing a mobile solution for positive identification of patients and access and entering of information, we believe it is possible to solve several of the problems present in the current ward round work process. The problematic issues (described above) can be summarized as follows:

- Preparation of all paper documents needed during the ward round is necessary
- Post-processing (documentation) of information created during the ward round is necessary
- Documentation is performed in several steps, sometimes involving several people
- The nurses are only authorized to enter some, but not all kinds of information
- No reliable method of patient identification available
- In some departments the available time for the ward round is extremely short

The wearable computer system in design provides technical solutions to improve the issues mentioned above, but also reforms the way in which collaboration is performed. The new ward round scenario we are currently working on, is the following: all documents are kept electronically, and thus there is no more need to bring a cart with patient records along to all ward rooms. As soon as the doctor approaches the patient, the patient is automatically identified and all relevant patient information is loaded and can be accessed and viewed easily at any time. Further, all information created during the ward round can be directly entered into the computer system collaboratively by the doctor and a nurse. This means that virtually no post-ward round documentation has to be performed. By reason of her proximity to the doctor, the nurse is automatically authorized to perform all data entry instead of only some. In this case, the system assumes that the doctor has issued the information verbally as proof of correctness. Any unclear facts can be solved right away which minimizes the risk for documentation errors. Since all entered information is released immediately, there is no need to involve other doctors with little or no knowledge about the patients in question.

A new collaboration model

Both the doctor and the nurse utilize a mobile respectively wearable device enabling them to collaboratively enter information using a mixture of speech, touch and pen input. Since the doctor often initiates a workflow by identifying the need for specific actions in the patient's treatment, he starts by entering the type of action to be taken. Then he adds the most relevant details, which need the expertise of a doctor to be decided upon. The nurse can follow the doctor's actions on her device. Furthermore, she is allowed to interact and fill out other details, make appointments, define priorities etc. according to her own expertise or the doctor's instructions. Depending on the time available for each patient in the ward round, the actions of a specific workflow can thus be arranged appropriately between doctor and nurse.

The wearable technology allows for a great deal of freedom to shape different collaboration models and work flows. This is important because the way in which the ward round is performed in different departments of a hospital, or sometimes even by individual doctors within the same department, can vary to a very large extent. There are differences in how many people actively take part in the ward round or how active the doctor actually is himself in performing documentation tasks. Further, the time available to spend on each patient can vary significantly between departments. Some doctors like to intensively interact with the patient, while others like to concentrate more on the operational part of their work. All these differences have to be supported by the new technology.

User centered design of a solution

Within wearIT@work we follow a strict UCD approach to design. Therefore the end users, in our case the medical staff, are the focus of all our design activities. Two of these activities are described in detail in this section; the mock-up study and the functional prototype development and evaluation. The objective of these studies was to try out alternative designs and interaction techniques to be used in selected parts of the ward round work-flow. Firstly, we wanted to figure out to what extent the new gesture and pen-based (for the nurse) interaction design supports the actual workflow of a realistic ward round situation. Secondly, the aim was to come closer to an identification of the most efficient collaboration strategy between doctors and nurses.

Mock-up design and evaluation

The overall goal of the first mock-up study was to try out some basic interaction designs and techniques on selected parts of the ward round work-flow using several kinds of off the shelf hardware. Firstly, we wanted to figure out to what extent the mock-up interaction design supports the actual workflow of a realistic ward round situation. Secondly, the aim was to come closer to an identification of the most efficient collaboration strategy between doctors and nurses. Thirdly we used the study to identify possible ergonomic issues with the hardware used. Thereby, we focused on following ward round activities:

- Accessing patient data
- Accessing individual findings
- Organizing a laboratory analysis
- Organizing an examination

Of course, there are many other tasks involved in the ward round scenario, but the above mentioned activities can be said to be representative, considering that the interaction techniques/input and output modalities and the work-flow used for other activities would be similar to those tested.

Execution of the study

The mock-ups were constructed using Macromedia Flash (see Fig. 1). The ward round activities obviously require collaborative work between doctors and nurses. In order to support collaboration, two mock ups were created. Those were installed on a tablet PC and a PDA for the doctor and nurse respectively. The tablet PC was remotely controlled (VNC) to simulate missing system functions such as:

- Identification of the patient
- Automatic display of patient information as a response to identification
- Communication between the tablet PC and the PDA

Medical data and findings of a fictive patient were entered to assure a realistic feeling while interacting with the mock ups. With the help of the medical personnel from Steyr the medical contents of the mock-ups were created as realistically as possible.

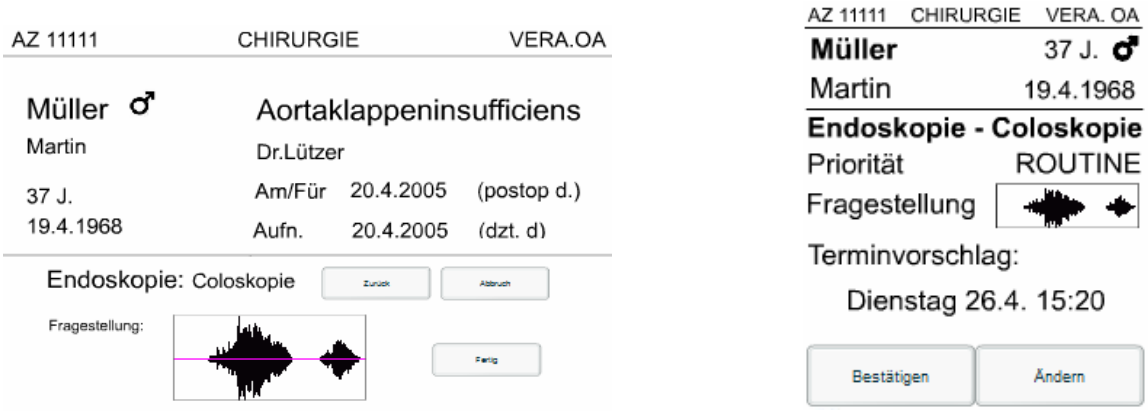

Figure 1 Macromedia Flash applications used in the mockup workshop. The doctor uses a tablet PC connected with a Bluetooth headset to specify an examination question (left). The nurse can immediately verify and edit the examination request on her PDA (right).

The participants in the study were five doctors: two surgeons, one orthopedist and two internists.
Two nurses were assisting, one for the surgeons and the orthopedist, and one for the doctors from the internal medicine department.

The tests were performed in a real patient room with one bed. The doctor and the nurse were asked to behave as 'normally' as possible for the arranged situation. The participants were introduced to the use of the tablet PC and the PDA. The participants were asked to role-play a typical ward round using the mock-ups available. Comments, opinions and suggestions from the participants were encouraged. Although discussions during the role-playing interrupted the work-flow to a certain extent, it was important to allow immediate feedback to avoid incomplete response after the tests.

Conclusion of the tests
The study was a success as a participatory design session. The mock-ups were complete enough to give a basis for discussion and answers to certain questions, but incomplete enough to allow room for comments and new ideas. The following list contains the main resulting requirements:

- Hands-free use on demand
  Users must be able to switch to hands-free use for short periods of time.
- Content display
  System must be able to display different types of content.
- Patient identification
  System must be able to automatically identify patients that are close (1-3m) to the wearable user.
- Voice recordings
  System must be able to record and play voice messages.
- Device placement
  Devices should be positioned so that they are not contaminated.

Prototype design and evaluation

As a second step, we built a working prototype taking into account the results of the mock-up evaluation. The new technology is especially tailored to the needs of doctors during their daily rounds. The technology that will help doctors in future is small and inconspicuous to wear. The main item is a computer the size of a belt buckle called QBIC [7] which is connected to the hospital IT system via wireless network. There is also an RFID reader, a wrist worn acceleration sensor which the doctor uses to navigate through the application and a headset.

Fig. 2 shows the scenario the prototype was built for. The doctor and nurse teams move around without paper, laptop or filing card. The doctor identifies the patient by means of the RFID reader on his wrist. The relevant patient files appear on the screen, attached to the bed, which can be used by the patient as a television or an internet terminal when there is no examination running. The doctor immediately gets an overview of all the important data around the patient, most recent results, current medication, x-rays or operation reports. With the acceleration sensor attached to his wrist, he can navigate through the application without using a mouse or a keyboard, thus keeping his hands sterile and free to examine the patient at any time. Using his headset, the doctor can record new findings or order x-ray requests related to his patients.

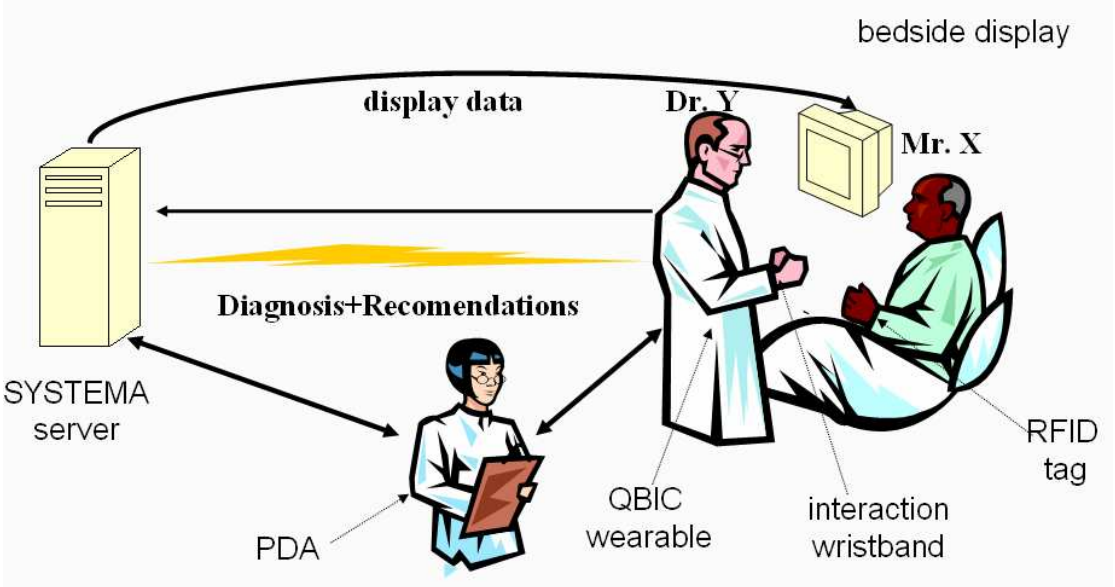

Figure 2 Prototype ward round scenario.

The nurse, next to him, receives the information on her PDA (see Fig. 3) from where she can view the appointment calendar of the x-ray department and immediately arrange an appointment for the patient.

Conclusions

Preliminary studies using the working prototype have shown that the envisioned system can indeed help the doctors and nurses in the ward round. However statistically relevant evaluations are still pending. The results and user suggestions of the preliminary study are currently being integrated into the prototype and the full-scale evaluation will follow shortly after this is done.

Preliminary user comments are as follows:

RFID: Patient identification through RFID was well received, as it allows a more secure identity check on the patient as well as automatic display of relevant information on the bedside computer.
Gesture interaction: Being able to interact with the system without using mouse and keyboard was a positive point for the doctors. However the accuracy and usability of the gestures needs to be worked on.
Collaboration: The mode of collaboration fitted well into some work practices and not so well into others. This is because our prototype did not allow for a per-ward customization of the work distribution between nurse and doctor.
All these comments will be integrated into the next generation prototype that will be tested by a larger group of doctors and nurses.

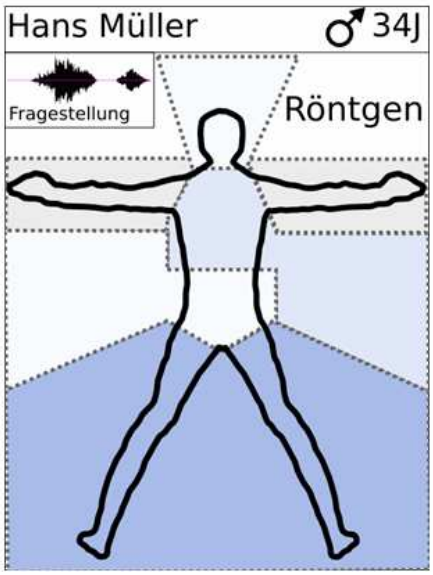

Figure 3 PDA sample screen managed by the nurse after the doctor submits an x-ray request.

Future Work

The new technologies offer advantages for everyone involved. The hospital and the nurses benefit from a lower documentation overhead as well as the optimized flow of information. The doctor finds all the necessary information at the patient's bed; his hands are kept free for the examination and he is able to spend more of his attention to the patients.
In the next phase, we will evaluate the developed prototype in a throughout user study. We will test the usability as well as the technical performance. Furthermore, we plan to apply our experiences with the ward round scenario to other collaborative scenarios in the hospital environment.

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