# Handheld Computing Devices in a Surgical Ward. Advantages on Clinical Information Sharing

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**Abstract.** At the Campus Bio-Medico University of Rome we have been using wireless networks and portable devices for more than three years to improve the quality of service. In this paper we describe the design of an application for handheld devices created to support the activity of the surgical ward, where daily documentation and maintenance of medical record quality is a crucial issue. We tested the introduction of handheld computers in medical records keeping and in communication among the surgical staff, ensuring coordination of activities and knowledge sharing about their patients. Remarkable issues were represented by: context-aware interaction, personalization of content management and interface design.

**Keywords**: mobile computing, adaptive interface, interaction-centered application, tailored decision support

## 1 Introduction

Patient data management is an area in which the risk of errors is high and in which PDAs may play a significant role [6, 10–12]. In a surgical ward, clinical information must be constantly and rapidly shared among the whole staff (physicians and nurses). The paper documentation (PPR, *Paper patient record*) is inadequate to support the task of providing fast and reliable decision elements. The PDA, allowing ubiquitous and consistent access to patient data, could help physicians take more precise, rapid and secure decisions.

In this paper we describe the design of an application for handheld devices created to support the activity of the surgical ward. Our hypothesis was that the use of handheld devices could enhance communication and quality of health records: physicians could improve their access to information by wireless connected PDAs, so that patient data could be available wherever decisions are taken.

After an accurate analysis of the staffs needs, we realized that content and presentation should be properly designed and not simply adapted for the PDA

starting from PC based solutions. Before solving problems due to some limitations of handheld devices (small screen, difficulties in writing and reading, short battery duration, etc.) we faced the importance of creating patterns: in order to convert the written note into EPR (*Electronic patient record*), we needed a structure. Therefore we converted the paper records kept by the staff from unstructured to structured data. We studied their daily recordings and created a paper form. Later on we produced an electronic prototype with context-aware presentation of data and where reading and writing were made easier through an adaptable interface. Some staff members tested the prototype for two months and we were able to improve it. Afterwards, the first version of the programme was released.

The solutions adopted are strictly connected to the needs of the staff, such as communication: we can therefore say that the design is not only user-centered, but interaction-centered.

In paragraph 2 we describe the project, starting from the analysis of users needs up to solutions adopted and interface design; some interesting issues concerning context awareness are described in paragraph 2.4.3; after presenting the results (paragraph 3), we tried to compare our work with the other teams' experiences.

## 2 The Project: an interaction-centered design

Campus Bio-Medico University of Rome, was a proper environment for our project: (i) the coexistence of the School of Medicine and the Bioengineering department in the same institution and building; (ii) the availability of a University Hospital with 15 wards (124 beds), intensive care units and a day-hospital unit.

The collaboration between bioengineers and surgeons began in May 2004: after the initial analysis and the software development, each member of the team received a PDA to allow rapid annotations of clinical data sharing them through a wireless LAN. In September 2004, the first phase ended and we collected feedback for a new implementation. The programme was modified and we started a second phase on the 1st March 2005.

### 2.1 Analysis

After getting introduced with the general surgical ward, we focused on the interaction activity. Our investigations concentrated on what each staff member's task: activities, content and behaviour.

Composed by seven surgeons and six residents, the surgical ward staff at Campus Bio-Medico takes care of: general surgical ward patients (15 to 20); out patients clinic (30 hours per week); surgical interventions (30 hours per week); diagnostic day hospital.

Surgeons, despite their other duties, are ultimately responsible for the correctness and completeness of medical records. However, senior surgeons may be

more involved in teaching, research and surgical activities than patient care, in which they are helped by residents. These ones, on the other hand, need the support of a senior, who controls their determinations, on the basis of clinical and instrumental data. The key elements in clinical work, particularly for constant postoperative monitoring are patients data recording and updating, and their rapid and precise knowledge sharing.

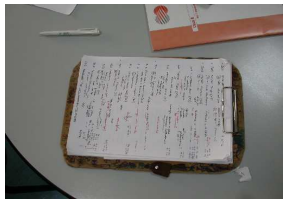
The normal activities of data recording are concerned with: patient history; physical examination; ongoing therapy (drugs); diagnostic/therapeutic workup (laboratory exams, X-ray exams, endoscopic exams etc); scheduled surgery.

The data set concerning a patient is normally compiled in different steps (Fig. 1):

1. a morning briefing between physicians and nurses takes place in the office;
2. handwritten notes are taken during daily rounds on a paper sheet over a wooden tablet;
3. events or changes in health condition are subsequently entered into the hospital database;
4. the entire body of information is summarized in a cumulative report at the time of patient discharge from the hospital.

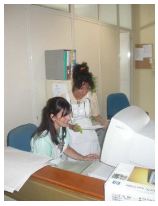
Each step depends on the physicians time resources, experience and routine to paperwork. The most important part of the clinical work is accomplished in the ward, but not all the notes written down during the visits are present on the patient record. These data are normally written on a paper sheet over a wooden tablet, which can be updated many times during the day, until the sheet is unreadable and is changed with a new one. The wooden tablet is a picture of the situation in the ward in a specific moment; sometimes it can be richer than the official clinical document, where some information are recorded only on patient discharge. This procedure causes the physicians a heavy burden for data transcription.

Morning briefing among surgeons and nurses



Wooden tablet

Manual updating of the clinical documents



Transcription of clinical data

**Fig. 1.** Data management in surgery ward

### 2.2 Methodology and content management

The analysts assisted more times at the morning briefing among physicians and nurses and followed the surgery staff during the round.

Three kind of information interweave in the daily recordings: the ward management (who is in which bed); the surgical programme (who is to be operated); the monitoring of patient in postoperative period.

In order to achieve a valuable result in a short time, we tried to convert the written note and studied the paper recordings of the surgical ward staff. In table 1 we list the information normally gathered for each bed.

**Table 1.** Surgical ward notes

| patient | hospital | surgical intervention | postoperative monitoring |
|---|---|---|---|
| name<br>surname<br>date of birth<br>age<br>diagnosis | admission date<br>date of discharge | procedure<br>date of surgical intervention<br>(if the surgical intervention has already been performed, number of post-operative day) | physiologic parameters:<br>blood pressure;<br>body temperature etc.;<br>diet;<br>ileus or gas canalization;<br>in/outgoing fluids:<br>parenteral fluids or nutrition;<br>urinary output etc. |

At first we studied the notes and created a paper form, with the most frequent options. Later on we converted this data model into a presentation layout for PDA, with some adjustments (see later).

Some members of the staff tested the system for two months. They gave us all the necessary feedback to improve the application. During this phase we modified the application to register a good level of satisfaction. We therefore proceeded in extending the test to the whole staff.

Even though the physicians normally use computers, they did not receive enthusiastically the PDA. They enhanced problems such as difficulties in learning a new system, doubts concerning the relative advantage of this system (is it faster than writing and reading data on the wooden tablet?), technical problems like wireless connection performance and power supply, doubts concerning the user interface (few predefined options and only small text boxes).

### 2.3 Hardware infrastructure and software development

The hardware infrastructure was already installed at Campus Bio-Medico University of Rome, where many doctoral works and researches have been focused on wireless technology and the use of handheld devices for clinical records. The most important was HISS (*Hospital Information System for Students*), a project carried out in 2003-2004 under the financial support of Hewlett-Packard [3–5],

which enabled students of medicine, nursing and dietetics to use wireless mobile devices while practising in all the wards.

Using the same SQL database server of the HISS project, with the possibility to record XML structured data, we developed a whole ASP.NET application. We added some tables to the existing DB, in order to distinguish the surgical notes from other information concerning patients' data recorded in other wards.

### 2.4 Interface design

PDAs are not able to manage complete electronic medical records or display complex graphic information, but they have been identified by users as excellent tools for managing clinical information and accessing it at the point of care. Nevertheless PDAs do have some limitations, due to reduced screen dimensions and uncomfortable systems of data entry, which can cause some difficulties in reading and writing. We tried to overcome these problems with solutions tailored on the needs of the staff.

**Interface design: information display.** In comparison to paper, PDAs can show only part of the information. We converted this 'bias' into an advantage, since we were forced to further systematize the contents already converted on the paper from unstructured to structured data. The more synthetic way of presenting the contents made patient data communication easier and faster.

The surgical notes were divided into more pages with a hierarchical structure: (i) the notes concerning all the ward; (ii) synthetic information concerning each patient; (iii) detailed notes on the problems of a single patient.

When we browse through the notes, the patient personal information (name, surname and date of birth) is always present, so that we know to whom the notes are referred. The structure of these pages has been designed to put in evidence relevant information.

1. in each page of notes, the screen is divided in two parts: the upper part, evidenced in gray, is destined to reading; the lower part presents *RadioButtons* for further data entry (Fig. 2.a);
2. the order in which items are displayed may depend on users preferences (in some cases, i.e. for diagnosis or surgical interventions, the order of records is inverted, so that the last is at the beginning, Fig. 2.b);
3. in case of more complex notes, only the last record is visible, while the previous can been seen accessing the archive through a button at the end of the note (Fig. 2.c).

**Interface design: data entry.** Patients personal information come directly from the admission database of the hospital information system. In the HISS project users could find this information by selecting of the number of floor of the hospital and bed. A copy the data contained in the admission database was


(a) (b) (c)

**Fig. 2.** Information display on pocket PC

then exported into a table of the HISS database and it was associated with all the recordings concerning that patient. We extended the search function giving the surgeons the possibility to search the information by department (displaying names, surnames and dates of births of all the patients of the surgical ward) or directly by name of the patient. This multiple choice is useful since the same data can be seen: (1) inside the context (the ward), or separately (the single patient); (2) knowing or not knowing the name of the patient.

After importing personal data from the hospital system, the users can insert data concerning: (i) diagnosis; (ii) surgical intervention; (iii) post-operative monitoring

In comparison to paper recordings, the electronic patient record has the advantage of inserting automatically some information: the date and time of data entry, the name of author of data entry. This system is studied to enhance communication among surgeons since whoever reads the notes can trace back to the author and knows at what time the patient has been visited.

A further effort was spent to obtain a flexible structure of notes through dynamically created forms, whose layout can change depending on the quantity and quality of information inserted. For instance, some windows are opened only if you need it. In this way we tried to avoid too long pages and, at the same time, to harmonize hierarchical structure and navigability.

Data entry was also simplified by using predefined options. However, in many cases, on specific request of the staff, we also gave the opportunity to insert free notes in text boxes of different sizes. For example, for the indication of the diagnosis and surgical interventions, the surgeons preferred free text notes

to ICD9-CM codification (which is used in the final document). In the HISS project we had developed a system to search for a disease into the wide database of ICD9-CM. But the surgeons did not like this function and wanted to be free to write whatever they wanted. However, at the end of the stay in hospital of a patient, they are compelled to write ICD9-CM codes for administrative purposes. Therefore some of them envisage an application for converting the plain text into ICD9-CM codes. As the codes are related to financial reimbursement by the Regional Health Authorities, errors in their attribution may lead to serious economical failures. We are aware that the typical Italian physician is not keen on using any codification at all and this behaviour causes some problems in Hospital Information Systems.

**Personalization.** The contents were personalized following different criteria:

- different relevant information is displayed depending on the user (physician or a nurse);
- since the surgical team is divided in two groups, each member of one group can visualize first the patients that are followed by his group and then the others;
- each user can save his interface view-state, so that when he goes back to work after a pause (or even the day after) he can start exactly from the point he was at the moment of stopping;
- each user can decide if he wants to work on-line or off-line.

**Context awareness.** We created an interface that dynamically adapts to the screen size: if the system is accessed through a pocket PC the dimensions of the pages are automatically resized to fit in the limited window, and the information to be displayed is reduced. A larger amount of information is available when the application is opened on a desktop PC. The two devices are used in different contexts. During the morning briefing among physicians and nurses the base for further recordings is compiled at a desktop PC in the office (this is the most massive part of data entry and it is done using a keyboard and a 17" screen). Afterwards, moving through the ward, data are just updated using the handheld devices. Each physicians can visualize the entire ward or only the patients he is taking care of, using a function similar to the 'favourite' links in a browser.

Besides working on-line the surgeons can also download the data they need and work at home, at university or in any other areas of the Campus not reached by the wireless LAN. When they return to the wireless enabled area they can synchronize the data. We studied three different ways of synchronization:

1. when the physician enters the wireless covered area, the synchronization starts automatically;
2. when the physician enters the wireless covered area, a pop-up windows on his display asks if he wants to synchronize;
3. entering the wireless covered area, the physician can open Active Sync (the programme which allows data synchronization between desktop PC and PDA) and send the data to the central database.

The third way was preferred by surgeons, since they claimed that sometimes the data are downloaded only for personal studies and they don't want neither the database to be automatically updated nor been asked for synchronization. Only when they really want to synchronize, they would issue the command.

## 3 Results

For the first months the PDA was used by some members of the staff, while others continued to write on the 'wooden tablet'. The comparison between electronic and paper records showed that undoubtedly handheld computers can improve both quantitatively and qualitatively the medical record. The information collected with PDA is more concise and precise. The possibility of modifying the notes allows an ordered flow of data, where all the data of postoperative monitoring are present, except the really unessential facts. Furthermore, in case of a double recording of the same piece of evidence, the note can also be eliminated. As can be seen in Fig. 3, the electronic record is at the same time more accurate and more synthetic than the one on the paper.

Data recorded on paper | Decoding the record | Data recorded on PDA | Discussing the data

**Fig. 3.** Comparison between PPR and EPR

Eventually even the more reluctant members of the staff accepted to use the PDA, not only in consideration of the advantages we have described, but also taking into account the possibility of getting ubiquitous access to lab, endoscopy and other tests, to the outpatient database, to medical references and manuals, etc. They were able to communicate every kind of data not only to the other members of the staff, but also to the nurses and to other departments of the hospital such as admission, maintenance, etc.

## 4 Related works

There are many works in literature reporting of the use of PDA in healthcare environments. Most of them are concerned with administrative and organizational task and only few concentrate on clinical work.

For example, in [8] the focus is on empowering mobiles devices, by extending the instant messaging paradigm, to recognize the context (location, timing, role) in which hospital workers perform their tasks. Reference [7] describes an application middleware for immediate high-quality multimedia communications in a hospital: by integrating a multimedia framework with an event-based notification system, the authors obtain a platform that can provide seamless, context-sensitive communications, which can adapt to users location. With "Bedside Florence" [13] nurses are able to electronically record notes and vital parameters such as blood pressure and body temperature right at the bed of a patient. The WARD-IN-HAND project [1] proposes as key elements "hands-free" interfaces through the use of voice and pen-based human-computer interaction and the use of widely available hardware and software to reduce costs.

Even rarer are investigations on interaction process inside a surgical ward.

A study by Lapinsky et al. [6], using focus group analysis of PDA users, found that patient-care data management by handheld device was not considered valuable, unless it is integrated into the hospital computer system. However, the long-term goal of integrating e-prescribing, physicians' notes, radiology, and

laboratory handheld capacities for physicians in outpatient clinics as well as in hospitals will dramatically improve functionality [9].

## 5 Future developments

After the introduction of PDAs, we monitored the staff. Our next goal is to monitor the patient in order to understand whether the electronic record can improve the quality of care into the hospital. Two groups of patients will be monitored: the follow-up of the first one will be done in the traditional way (paper); the other one with PDA. We want to know if a more precise and faster way of communicating can prevent postoperative problems and to which extent it is possible to predict them.

Furthermore, analysing PDAs recordings we can assess standard procedures, so that the physician has also a tailored decision support in his activity.

Last, but not least, we want to know if the trainees take advantage of the use of handheld devices. Already the HISS project investigated the issues of handheld devices in a learning environment. In this case we want to go far beyond and see if students can be best prepared to future professional activity.

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