Handheld RFID Patient Safety Improvement – Case Study in Wan Fang Hospital

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Abstract

Nowadays, medical centers are working on setting a safe medicating environment by using information technology. This research is to build up a wireless handheld RFID patient safety enhancement system for medical personnel, which combines Radio Frequency Identification (RFID) technology, IEEE 802.11 (Wifi) Locating Engine, Personal Digital Assistant (PDA) and Front-Monitoring System. The goal is to improve patients' safety, communications among medical staff and medical staff and patients, medicating quality, and efficiently practicing in medical processes.

Medical staff experiences a high level of mobility. This phenomenon makes hospitals ideal application environments for pervasive or ubiquitous computing technology. Through the combination of information techniques, we can identify patients and medical staff by non contact identification, do real-time verification, getting medical record and colleagues' location immediately and provide context-aware service. Meanwhile this system can record the contact history of the interaction between medical staff and patients. It can also give alarm when clinical decision engine reporting a high risk testing result, notify of new result, provide medicine safety suggestion, improve the mobility and instantaneousness of patients' medical information and create a safe environment for patients.

Keywords: Patient Safety, RFID, Wireless Locating Engine, Context-Aware Service

1. Introduction

Taiwan Health Reform Foundation also point out that such research illustrated that if the number of patients cared by one nurse increase to 8, the mortality of patients in 30 days increase 31%.

The U.S. healthcare evaluation organization Joint Commission on Accreditation of Healthcare Organization (JCAHO) [10] proposed seven goals for all healthcare organization to improve patient safety, including increasing the accuracy of patient recognition, improving communications among healthcare service providers, elevating the safety in administration of high risk drugs, avoiding mistakes in operation procedures and operation sites in patients, enhancing the safety of infusion pumps usage, reducing the risk of infection through healthcare [9].

Also, in 2004, IOM [11] had proposed that in order to improve patient safety during healthcare procedures, and one of major tasks is to use medical informatics techniques actively. In one way, real-time, accurate information are provided to the healthcare personnel; whereas information techniques are used to unveil adverse or near mistaken operations during healthcare processes. Healthcare procedures can be improved or redesigned based on this point of view.

Wanfang Hospital is a medical center hospital which works actively in integrating patient-oriented healthcare service system. Several goals are expected: 1. secure the patient safety, 2. develop patient safety information system and building a complete hospital-wide patient safety report system, 3. enhance patient-oriented healthcare quality.

In 2004, the Center for Patient Safety Informatics (PSI) was formed to promote the construction of infrastructures and applications of patient safety information system in Wanfang hospital.

In early stage, a medical information interaction model was built based on interactions among patient basic information, pharmacy, laboratory examination, diagnostics, and medical devices. This model is further combined with communication techniques and plans a series of patient safety information infrastructures and applications. The patient safety information system is partly described below.

Currently, Wan Fang hospital will issue a report while examination and radiology results are judged as high risk cases. These notifications will be sent with instant message or e-mail actively as soon as possible. The healthcare personnel are informed of the state of patients in real time, and take suitable procedures to avoid any possible delay.

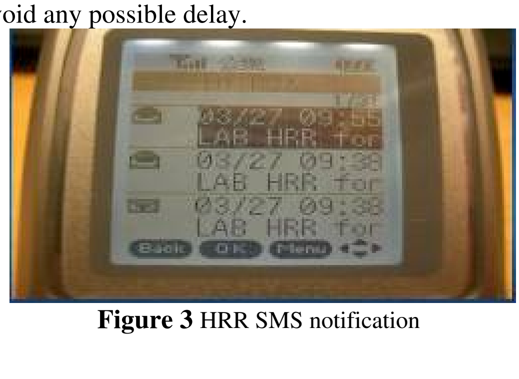


Figure 3 HRR SMS notification

Adverse Event Reporting System (AERS) provides an informatics interface to improve communications among healthcare service providers. Also, the records that are stored in reports can be fed to Computerized Physician Order Entry (CPOE) and produce analytical reports, avoiding adverse responses of patients from recurring (Figure 4).

Figure 4 Adverse Event Reporting System (AERS)

In the adoption of novel technologies, Wan Fang Hospital introduces radio frequency techniques in the emergency area to verify patient identity through non-contact mean. Afterward, the integrated patient medical information can be obtained; interactions among healthcare personnel and patients are recorded; high risk laboratory examination results are highlighted actively; hints for drug use safety are provided (Figure 5). All in all, these procedures improve the accuracy of patient healthcare information promptly and construct an environment for patient safety.

Wan Fang Hospital has constructed a patient safety information infrastructure, and uses Web Services (developed by Visual Studio.NET platform) to integrate related patient safety information within the hospital. Wan Fang Hospital also attempts to build an information exchange platform for data integration and program component sharing. Each functionality is highly flexible and innovate applications are possible. Also, through the dynamic combinations of services, hospitals and clinics can respond to specific services or projects rapidly.

Hospitals are complex information-rich environments including a significant technique and computing infrastructure, the need for coordination and collaboration among specialists with different areas of expertise, an intense information exchange, and the mobility of hospital staff, patients, documents and equipment [2].

Unfortunately, the personnel usually have to use specific fix computers to access hospital information system, not to get immediately his/her colleague's location and need a convenient interface to get the patient's information.

Figure 5 Emergency RFID system

For highly mobile healthcare personnel, unnecessary efforts and times are wasted with these inconvenient. In this work, we propose a concept that front-end system can be carried around by healthcare personnel, access hospital information system (HIS) everywhere, get the location information of other colleague anytime, and use RFID module to improve patient identification procedure.

In Section 2, we introduce an overview of RFID application in healthcare systems. Section 3 we describe the research method we use. Section 4 presents the overall architecture, including the wireless locating engine, of our system. Section 5 is the result and discussion. Finally, Section 6 we present the conclusion.

2. An Overview of RFID applications in healthcare systems

Radio Frequency Identification (RFID) has been applied in various fields, including libraries, malls, and MRT. RFID has following characteristics: 1. non-contact data accessing; 2. miniature and variation of tags; 3. well adapting to various environments; 4. high data security; 5. reusable tags; 6. no restrictions on directionality; 7. large data contents [2]. With These seven characteristics, RFID is well suited to perform identification in hospitals.

Last few years, most studies on the applications of RFID are focused on improvement of supply chain management. Seldom did they apply RFID to healthcare. In year 2005, the Compound Annual Growth Rate (CAGR) of RFID in healthcare is 54.3%, which is the highest CAGR among other application domains.

Several kinds of RFID application in healthcare is carry out such as tracking the movements of patients in ER, recording the time spend in ER, and using RFID information to improve patient waiting time [4].

In nurse station, using identification technology to authenticate healthcare personnel and build real-time shift database, to provide information on patient clinical treatment and queries on shift data. It also provides more basic patient information for later check and applications. These procedures can replace paper works for confirmation and control in healthcare and shift procedures. This could further reduce manual operations and improve the accuracy of patient medical information promptly [4].

During the outbreak of SARS, RFID was also applied to related epidemic prevention tasks. In the R&D program supported by MOEA, ITRI and Ton Yen Hospital developed "RFID tracking and control system" in collaboration, this system can track and segregate possible infected personnel rapidly. Later on, they developed a "RFID medical instruments management system". This system can manage the access personnel, quantity, and locations of instruments. It can also monitor the on shelf periods.

Sun Yat-Sen cancer center applies RFID technology to pharmacy matching system, to avoid controversies in misuse of drugs.

For the improvement of patient safety, Taipei Medical University Hospital puts identification RFID tags on patients in operating room and provides related information, images, and audio to help medical personnel identify the patients. This information could further confirm the sites to be operated [6].

3. Methods

In the planning phase of the study, numerous interviews have been held among medical personnel from Wan Fang Hospital (including physicians and nurses) and the development team. During interviews, we discuss system requirements and design the system architecture and operating procedure. Later on the development team implements the practical system. In Table 1, we list major requirements from the medical personnel and our corresponding improvements.

4. Developmental environment and system architecture

We introduce a simple scenario of pervasive computing environments in hospitals.

While Dr. Lin is making his regular round in the hospital, his PDA allows him to review the patient's healthy information or various kinds of reports wherever he goes, avoiding moving to the specific computer.

Table 1 Strategy for Improvements

Requirements	Improvements
Identification	RFID and authentication
Improve interactions between medical personnel and patients	Medical personnel can use PDA to display patient information, including reports, diagnostic descriptions, drugs, etc. Through this information, personnel can understand the status of patients rapidly and discuss with the patients.
Improve clinical notification system	High risk report (HRR) from expert system displayed in highest priority, notify medical personnel to check these reports
High risk drug use safety	Queries on patient drug-usage and online drug dictionary
Reduce risks of infections from healthcare	Through usage and RFID reading log, once the outbreak occurred, the system can help medical personnel to understand the contact history between medical personnel and patients.
Hospital personnel wants to check reports on patients anytime and everywhere.	Personnel can use this system to download all kinds of patient reports from HIS through hospital local wireless network.

Upon checking the patient in bed 222, he downloads the bed 222 patient's data through reading the patient's RFID tag. At the time his PDA alarms that this patient has High Risk Reminder (HRR) reports, judged by clinical decision engine. Dr. Lin must checks these reports immediately to give a proper treatment. While analyzing these data, Dr. Lin has a little doubt and needs to discuss with the resident physician, who is also informed that HRR report exists by the message on his cell-phone. Dr. Lin's can use his PDA to find a nearest physician's location on the map and call the physician over. After a brief discussion and giving proper treatment, Dr. Lin moves to bed 223. He finds a notification on his PDA alarming him that this patient's new examination is on the line to review. Dr. Lin can use his PDA to these examinations without moving and discuss with the patient. This scenarios bridge the gap between medical staffs and patients.

There are five major components in this system, including "PDA front-end monitor system", "Wifi location engine", "medical information service platform", "clinical decision engine", and "medical databases" (Figure 4).

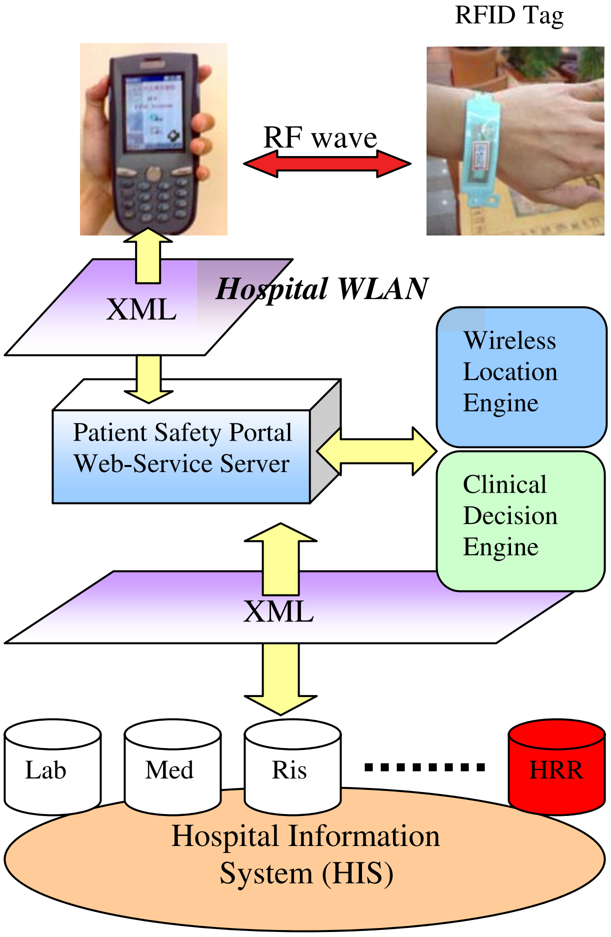


Figure 4 System Architecture

4.1 Medical database

"Medical Database" is the relational databases storing patient-related data. The databases keep track of all histological data regarding patients, and provide all sorts of information required by various software system built for the hospital, this data, including basic information, registration time, drug usage, diagnosis, treatment, examination results, and information from shifts. These databases can speedup the information exchange procedure in the hospital.

4.2 Medical information service platform

The major goal of medical information service platform is to integrate different database tables in the hospital, and extract medical information required by medical personnel. These services are packaged into many Web Services and medical system programmers can use these Web Services as components to develop novel applications (Figure 4).

The advantages for constructing this platform include: 1. programmer do not need to directly operate on numerous large databases distributed in the hospital. 2. Indirect accessing to databases avoids human-made damage to databases, also avoids database synchronization problem. 3. The extensibility of such hierarchical platform is pretty well. Different services can be constructed for different systems. This facilitates the introduction of new techniques to the hospital.

4.3 Clinical decision engine

"Clinical decision engine" is an expert system combine expertise of professional medical researchers. These professionals collect and build all sorts of clinical information to be used in the clinical system. Possible mistakes in operations are included, so as the system can provide hints to medical personnel at any time, which in turn improve patient safety. Related decision information includes clinical directions, drug usage directions, and examination reports thresholds. The decision engine can provide clinical directions to medical personnel. Also, clinical reports on patients can be compared with related knowledge stored in decision engine, and the data of patients exceeding threshold will be passed to medical personnel immediately.

4.4 Wifi location engine

As a common wifi location mechanism, we divide whole indoor space of each floor into several small cells and then choose some reference points to gather the signal strength of access points of the hospital WLAN in these cells. Since these rooms have concrete walls, the radio signal strength of each room is quite different. We can construct a radio map for every floor with these power signatures. These cells are distinguished by the mean and standard deviation of their signal strength [9].

To reduce the computing burden of the PDA, all computing jobs is done by the server and data for location estimating, such as signal strength, is stored to the server-side storage. The front-end monitor system on the PDA just needs to send the gathering power signature of near access points to the server and then gets the returned estimated location from the location engine. After getting the estimated location, medical staffs can see the location of colleagues and specific medical devices on the map showed on the PDA. Through this locating mechanism, we can keep track of personnel's location information to enhance the communication procedure among personnel.

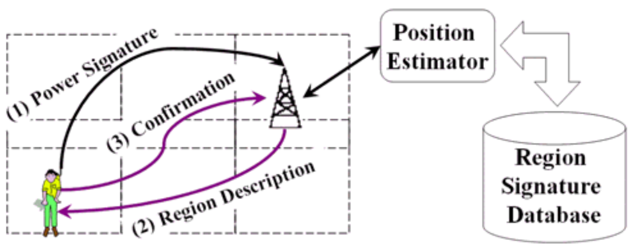


Figure 5 Wifi location engine

4.4 PDA front-end monitor system

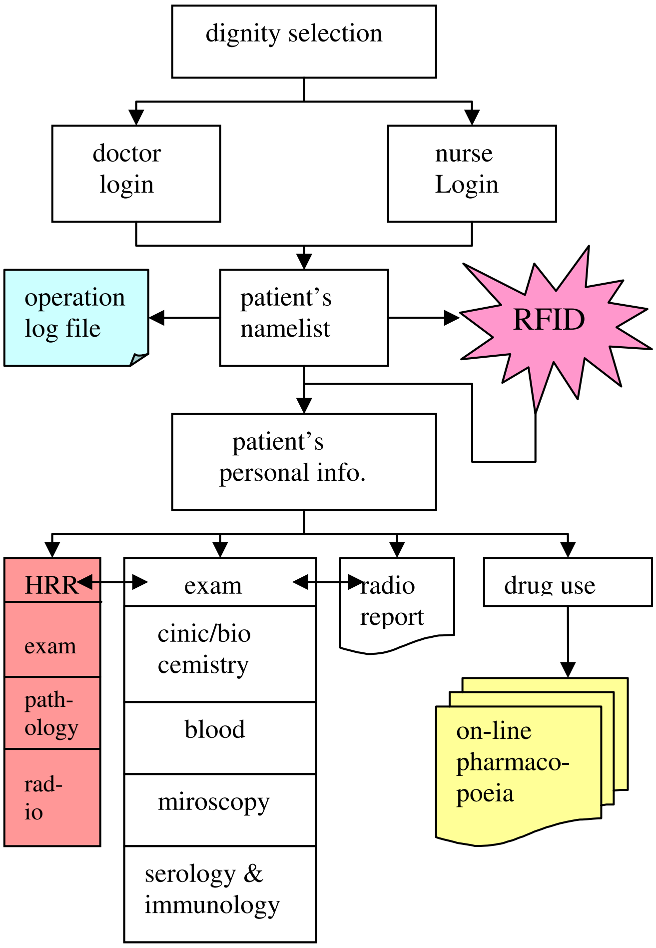


Figure 6 PDA interface system diagram

The development environment of this interface is Microsoft Visual Studio .NET 2003. The designed operation flow of the system is illustrated in Figure 6.

To physicians, the patient list only includes information of patients handled by the physician (Figure 7b) to personalize the presentation of information to the doctor.

To nurses, when switching to patient list, they can select all rooms in the hospital and view patient information based on rooms and floors to adapt to the mobility of daily work flow of nurses (Figure 7a).

The icon in the left (Figure 7a, 8a) is used to distinguish high risk patients, which is judged by the clinical decision engine. If the icon is in red, the patient has at lease one high risk reports; otherwise, the patient is in the normal group. Such design helps personnel to identify high risk patients and view their room numbers and bed numbers as soon as possible. This design enhances the performance of high risk notification system. User can press the column head of each column, e.g. serial number, the patient name list will be sorted based on the pressed field to provide multiple ways to review

(a) (b)

Figure 7 Front page – patient information

The system can also keep track user's operation flow (Figure 13). User can check their own usage log, including every action and respective time after login, on the PDA. Medical personnel can rapidly lookup which room, patient, or RFID tag has been inspected. Also, analysis can be performed on these usage logs to improve system performance and work flow. Hospital can also track the contact information between physicians and patients through these logs.

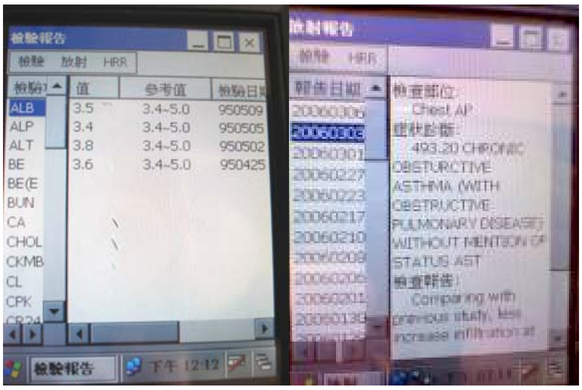
If the medical personnel want to obtain more detailed information about a specific patient, s/he can double-click on that patient or read patient's RFID tag to bring up detailed patient information (Figure 8a, 8b).

Detailed patient information (Figure 8b) displays patient name, room number, HRR icon, gender, age, days in the hospital, date of admission, physician, resident physician, diagnosis at admission, and diagnosis description. Also, through clicking the four buttons at the bottom, one can view the examination report (Figure 9a), radiology report (Figure 9b), HRR report (Figure 10), drug use, and online pharmacopoeia.

(a) (b)

Figure 8 Patient list and basic information

Examinations include biochemistry, hematology, micrology and serum immunology.



(a) (b)

Figure 9 Examination and Radiology Report

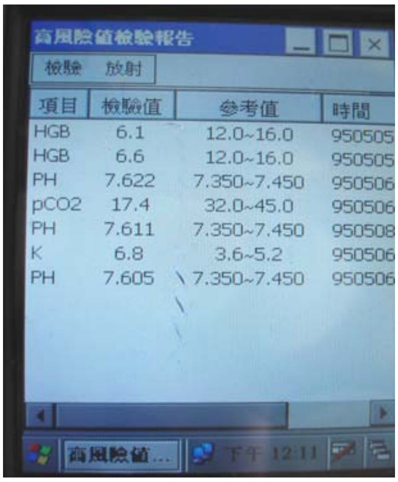


Figure 10 High Risk Reminder Report

To date, the most popular medical applications on handheld devices are the ones that provide access to reference material such as drug information database [3]. The use of drugs change frequently and more than 20,000 drugs are available in the hospital. To avoid mistakes in drug use, we also provide query and display of patient drug use. We divide each day into 24 hours, when users select one of these time slots, the statistics of drug use during the period will be presented, including drug code, drug name, dosage, status, route of administrator, frequency, and unit (Figure 11a).

Medical personnel can query the drug in the online drug dictionary based on the selected drug number (Figure 11b). More information about this drug can be obtained, including: image of the drug, indications, contraindications, pharmacology, etc. These information help medical personnel to explain these drugs to patients, also reduced mistakes during drug using

4.5 PDA

Through a series of test and compare, we adopt Unitech PA960 (Figure 12) as our handheld device. This is an industrial PDA with a built-in RFID reader, a barcode reader, large buttons and a 802.11 wireless network adapter. It is more suitable for medical personnel, with higher mobility, to carry around than common commercial PDA devices

5. Result and Discussion

We have showed our system prototype described above to the hospital personnel and teach them how to use. We get good responses on this procedure. There are still some points we must take carefully. The computing power of a PDA is weaker than that of a common desktop computer. To make the operation smooth, responsive, and user friendly, special cares are taken in the design of work flow and switch of forms.

(a) (b)

Figure 11 Drug use and only drug dictionary

Figure 12 Unitech PA960 PDA

Our tests and discussions have revealed the following points:

1. Simple operation flow. For example, in the programmer's view, the activation of RFID reader requires 5 or 6 instructions and several parameter initializations. For the common users, these steps should be combined into one button-click to reduce the manipulation burden. For heavy loaded medical personnel, simpler operations are better. Complex procedures will lower the acceptance of the system.

2. The presented medical information format should be simple and clear. The medical personnel face multiple patients and various reports everyday. They have to switch their attentions between patients and reports. The theme and functionality on each form should be

presented clearly to save operation time. In early design phase, we tried to display all information in one form on the screen. However, when tested by the medical professionals, it was complained that the forms are too complex and not easy to extract required information. Therefore the information should be prioritized and the forms should be tabularized, to avoid display of too much information or texts. The programmer might search non-official SDKs [12] from Internet to present data in a more complete fashion.

3. The accession of Web-Service platforms should be combined to speed up the data gathering procedure. Our front-end monitor system on the PDA accesses medical database through IEEE 802.11 wireless networks. The connection procedure of IEEE 802.11 wireless network is much slower than wired Ethernet. Based on our experiments, access to server and call a Web Service takes 3 to 5 seconds (based on the amount of data). If continuously access database in a single operation, users have to wait a long time and might misinterpret the system crashed. This situation should be avoided in both the client and server side.

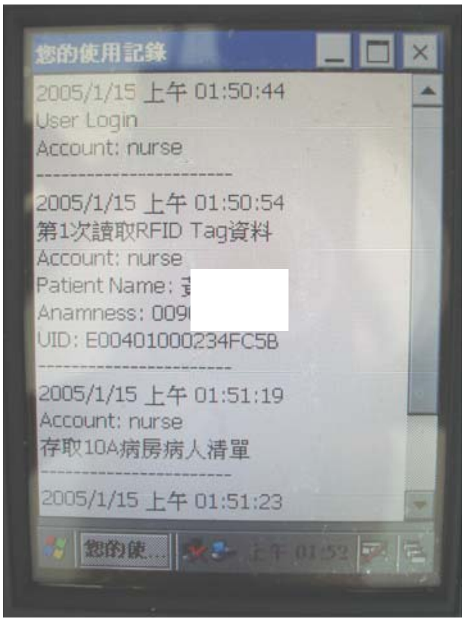


Figure 13 Log of user operations

4. Log of user operation flow. Tracking and analysis of user habits is critical to system development and research. With mathematical analysis of this information, we can not only improve system performance, but also provide more active services in a context aware manner [5]. Also, these log information are helpful in debugging the system. Furthermore, medical professional can get a grip of their work progress and contact history through the inspection of these information (Figure 13).

This system has been transferred to Wan Fang Hospital for testing. Therefore the medical personnel can operate the system after short educational training. They are also satisfied with the system.

Figure 12 Educational training

6. Conclusion

The major goal of this study is how to use informatics techniques to help medical personnel enhance their daily work procedure, improve patient safety and spread properly the use of hospital information system.

There are seven goals for us to improve, including: 1. identification mechanism, 2. interactions between medical professionals and patients, 3. clinical notification system, 4. high risk drug use safety, 5. lower risk of infection through healthcare, 6. inspection of all kinds of reports, 7. inspection of basic patient information.

We have presented our efforts on this handheld interactive medical information system prototype, and it is operating online in hospital.

Hospital is a technical and context rich environment to apply mobile, ubiquitous, and pervasive computing. We hope this system to be a good reference for development and distribution of handheld medical information system in a hospital. We will continuously add more context-aware services to this system and make it powerful in the future. as a direction toward the development of a pervasive computing environment.

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