International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:5, No:11, 2011

Pervasive Computing in Healthcare Systems

Elham Rastegari, Amirmasood Rahmani, Saeed Setayeshi

Abstract**—**The hospital and the health-care center of a community, as a place for people's life-care and health-care settings, must provide more and better services for patients or residents. After Establishing Electronic Medical Record (EMR) system -which is a necessity- in the hospital, providing pervasive services is a further step. Our objective in this paper is to use pervasive computing in a case study of healthcare, based on EMR database that coordinates application services over network to form a service environment for medical and health-care. Our method also categorizes the hospital spaces into 3 spaces: Public spaces, Private spaces and Isolated spaces. Although, there are many projects about using pervasive computing in healthcare, but all of them concentrate on the disease recognition, designing smart cloths, or provide services only for patient. The proposed method is implemented in a hospital. The obtained results show that it is suitable for our purpose.

Keywords**—**Pervasive computing, RFID, Health-care.

I. Introduction

PERVASIVE computing aims to provide people with a more natural way to interact with information and services by embedding computation into the environment as unobtrusively as possible [1]. The range of use of pervasive computing is very large. Emerging pervasive computing technologies are applicable in many areas of life such as healthcare, sport and education. They can be found in domestic appliances, cars, tools and even clothes. Smart homes [2]-[3] equipped with sensors and reasoning algorithms that can support their occupants' daily activities are currently being developed. Such smart homes are designed to make life easier and safer. This can be accomplished by systems that are able to detect falls or deviations from usual behavior in addition to enabling communication with appropriate authorities in case of emergency [4].

Moreover, smart homes are not the only examples of using intelligent devices to improve the quality of life. Guides showing the shortest route from one place to another [5], designing and prototype implementing of a system which can deliver pervasive learning services in a campus domain[6], and providing pervasive computing services in the hospital and in the community [7]-[8]-[9]-[10]-[11]-[12] are other examples of emerging pervasive computing technologies.

One of the major consequences of pervasive computing is the disappearing computer, i.e. computing (and communication) power is increasingly embedded into devices and everyday artifacts. When people interact with these "smart objects", they might not be aware of the fact that in the background, data reflecting their current situation and behavior is collected, exchanged, and processed. This processing is going on, in many cases, for the benefit of users, but could also be carried out in the interest of other parties. This gives room to privacy and security concerns. However, in a healthcare environment, the benefits might easily outweigh the risks. Patients are willing to give up a big portion of their privacy for the sake of medical treatment, though that must not lead to disadvantages outside this context.

According to one study [13], thousands of patients die each year in hospitals due to (mostly avoidable) medical errors, imposing substantial cost on national economy. This study was performed in the U.S., but similar numbers are likely to apply in other countries. It is assumed that improving the procedures related to treatment can help prevent many medical errors. This clearly indicates that high potential lies in the application of pervasive computing technology to process improvement. For example, medication errors are a severe problem in healthcare. In the U.S., such errors are estimated to account for 7000 deaths annually [14], and are often due to bad handwriting and similar problems [15]. Such errors could be largely eliminated through better auditing capabilities, introduced by pervasive computing technology, such as Radio Frequency Identification (RFID). Reducing medical errors, is one of the advantages of using pervasive computing technology in the hospitals.

Pervasive computing research covers a wide range of areas. It involves distributed and mobile computing, sensor networks, human-computer interaction, and artificial intelligence. Knowledge of all of these disciplines is essential to the creation of systems that are truly accessible to users. Researchers need to combine knowledge from medicine, physiotherapy, psychology, and information and communications technology to create more user-centered systems. When the design of a pervasive healthcare system is considered understanding of its intended users is essential. An appropriate user description leads to a better understanding of the user's needs and a better design of the pervasive healthcare system.

For that reason we propose a scenario based on EMR database, in that, hospital space is divided in 3 spaces. Patients are instrumented with vital-sign monitors. Physicians and nurses in this scenario have wireless PDAs. And all of them are instrumented with a means to determine their locations.

The remainder of this paper is organized as follows. Section 2, proposes a scenario in a hospital with its requirements and services that might serve. In Section 3, we present our approach and implementation of our system. Finally, Section 4 presents our conclusions.

E. Rastegari is faculty member of Computer Engineering Department, of East Tehran Branch, Islamic Azad University,Tehran, IRAN (phone: 0098 917751 0401; e-mail: erastegari@gmail.com).

A. Rahmani is faculty member of Computer Engineering Department, of Science and Research Branch, Islamic Azad University, Tehran, IRAN. (e-mail:rahmani@srbiau.ac.ir).

S. Setayeshi is faculty member of Computer Engineering Department, of Amir Kabir University, Tehran, IRAN (e-mail:setayesh@aut.ac.ir).

II. Pervasive Health-Care Scenario

In our scenario, all Patients are instrumented with vital-sign monitors and with a means of determining their location. Physicians and nurses in this scenario have wireless PDAs, also are instrumented with a means of determining their location. Context-aware applications, optimize physician recognition, support nurse triage, simplify the user interface to pervasive devices, provide additional data for billing reconciliation, and provide clinical communications.

Availability of location information can also help to improve other processes within a hospital. Decisions are often based upon information about the physical location of a person or an object. This information including person's name, date, time and location is sent to a central panel from all locations. For example, if a patient gets into a critical condition, location of the patient and the nearest doctor are sent to the central system which calls the nearest doctor and nurse to the scene. This system can inform the nearest doctor or nurse with an alarm. This alarm may be a red icon which appears on the screen of staff's PDA or mobile phone and shows the patient's room number. It also may be a critical condition sound message informing the doctor and nurse of the patient's room number through their headphones.

As this alarm is received by the doctor and nurse, they go to the patient room immediately. As soon as they enter the room, a subset of the EMR of patient appears on the screen of existing computing system in the patient room. The Doctor reviews the patient's EMR and vital-sign, and writes the necessary orders in a special form that is automatically loaded on the computing system (such as doctor's PDA or computer of patient room). Laboratory, Radiology, pharmacy and physiotherapy as related parts of a hospital must have a database. When a doctor writes orders in the related fields of form, the databases of the central system are updated based on his/her orders. When the medical personnel of the related parts see the patient's name and doctor's orders, they perform the necessary works. Doctor's presence in the patient room is noted by the smart space and linked to a back-end system for patient accounting.

As the doctor enters his/her room, the computer turns on automatically, and latest medical information of the doctor's patients are loaded on his/her computer. So, the doctor can check patient's EMR and vital-sign and if necessary writes the appropriate orders.

In our scenario, hospital space is divided into 3 parts: 1- public spaces such as the reception where any person can enter. 2- Private spaces, such as the doctor's room, where only one person can enter is himself/herself and the alarm can be heard if necessary. 3- Isolated spaces such as the operating room where only specific staff can enter, and no alarm can be heard afterward. Consider a doctor in an operating room; it is very likely that this particular physician is currently busy and shouldn't be contacted on matters of low urgency. The Presence of the doctor in the operating room is recorded by the central system. So, in cases of low urgency, the doctor won't be paged.

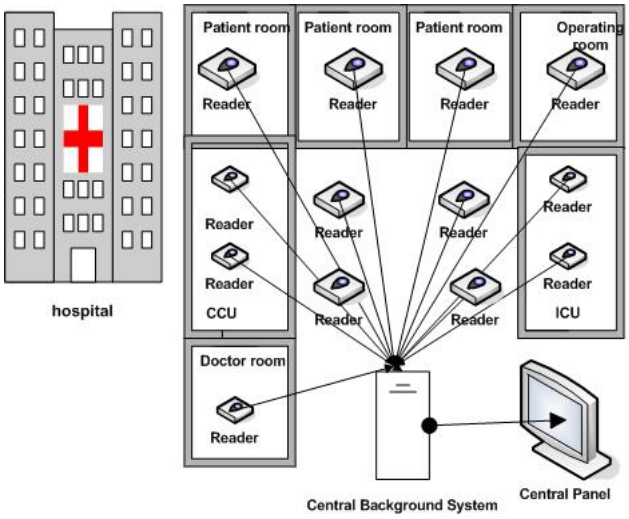

Fig. 1 Pervasive Hospital System Model

A. Basic Requirements

In order to improve healthcare, a pervasive health system needs to address several main requirements:

a) Have a design that is understandable for all users. A pervasive health system needs to target users; expert users who are familiar with the system and non-computer literate users who have no or little knowledge about computing.

b) Supports policy to control access to services. Having a healthcare system that can control personnel's' behavior in accessing services would also be an advantage. For example, nurses are not allowed to access the service of "writing order". This is possible by using policy mechanisms to control mobile service operation in pervasive hospital environments.

c) This pervasive system must support awareness and understand personnel's contexts or activities. Having the ability to sense the personnel's contexts and delivering the relevant information would certainly help medical staff in detecting condition and supporting services that might be needed.

d) Supports proactivity [6]. It is necessary to Have a proactive system that could sense the personnel's and patients' current situation and automatically delivers relevant services to them. For example, when a doctor enters his/her room, at a determined time, electronic medical record and vital-sign of his/her patients appear on the screen of his/her computer.

e) Availability of the central background system is essential in order to provide timely feedback to the patient and provide backup of all data sent from all spaces. This system manages all processes and services in a hospital. Manipulation of data in a health care system could have a fatal impact; therefore the integrity of data is of major importance, that means regardless of the places where data are kept or in transit, their integrity must be protected.

f) Having necessary database is essential. In this scenario several necessary databases such as drug database, laboratory database, radiology database (that includes CT

scan, M.R.I, sonography, mammography), physiotherapy database, patient database, people tracking database, personnel data base (that includes doctors, nurses and other personnel) and accounting database are considered.

g) Different type of sensors and monitoring devices must be used in pervasive hospital system in order to gather information. For example the ability to collect data from the patient is made possible by using biomedical sensors and other clinical equipment.

h) Using RFID Technology. RFID is an Automatic Identification and Data Capture (AIDC) technology that uses Radio Frequency (RF) waves to transfer data between a reader and an object for the purpose of identifying, categorizing, and tracking the object. RFID is fast, reliable, and does not require line of sight or contact between readers and tagged objects. With such advantages, RFID is gradually being adopted and deployed in various applications, such as supply chain systems, warehouses management, security, hospitals, highway tolls, etc [9]-[17]-[18].

i) Data Aggregation. Data Aggregation could be needed for various RFID data processing tasks. For example, we may need to count the number of products passing through the door every hour, or monitor the max/min blood pressure of a patient throughout the day.

j) Access Control System. Having access control policy system in the hospital is of major importance. As this system allows a doctor to access the communication service completely, but a nurse cannot be allowed to access the order form of communication service.

B. Some Useful Necessary Services

The pervasive health system enables the user to receive a relevant set of services that fit his/her current context. Some sample services which are useful for pervasive health environments are:

a) Electronic Medical Record (EMR) Service: personal properties and medical history of patients must be recorded in an information record system from the time a patient enters the hospital until she/he leaves.

b) Communication Service: this service is used for communication between all parts of a hospital. For example doctors can communicate with the laboratory and send their lab orders. After performing the orders, results are sent to the central background system and saved as EMR.

c) Mobile Reminder Service: the system that reminds the personnel of important tasks or activities which are supposed to be completed at a particular time. For example, a doctor sets a reminder regarding the due date of the surgery to the nurse supervisory. This reminder will be sent and downloaded onto the central system and nurse supervisory computing device.

d) Mobile Navigation Service: it is necessary to guide personnel and other people to find a certain place (e.g., CCU) in a hospital.

e) Automation task Service: a service that performs a task automatically. For example auto-downloading the patient medical record when the doctor steps into his/her personal room.

f) People Tracking Service: this service helps to follow every personnel in a hospital. It is useful especially about doctors. For example by having doctors locations; there is no need to page them in all wards when they are urgently needed in a special ward.

III. Proposed Method

In human-centered Pervasive Computing systems, the human is integrated into the network and is treated as part of the network composition. The system knows the human like a network node in the network. The pervasive computing devices interacting with the human are considered as servers which can proactively serve human. In this research, Master-Server paradigm is used that shown in Fig. 2, for our pervasive health system.

This paradigm has service request and response. So the user can request services anytime and anywhere. This paradigm also provides services proactively based on human needs [16]. For designing and implementing this paradigm we used RFID system.

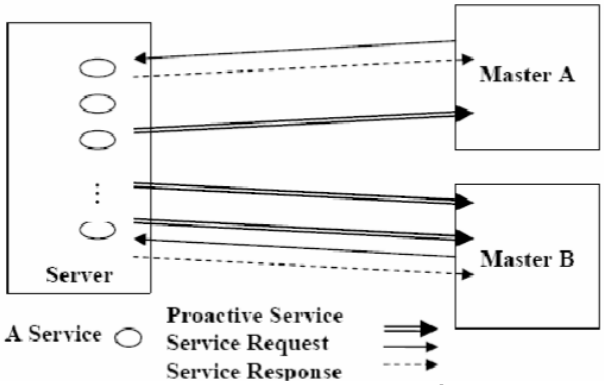

Fig. 2 Master-Server Paradigm

A. RFID Technology in Our Pervasive Hospital

RFID technology makes it possible to i) collect large amount of data for tracking and identifying physical objects along their history and ii) real-time monitoring of physical objects and their environment for monitoring applications.

In our work we assumed that the hospital space is divided into several spaces, each of them equipped with a reader. Each patient room has a reader, and there are several other readers deployed throughout the hospital. Context information about patient condition, personnel information, devices and drug information are provided from patient monitoring system (such as vital-sign), sensors and RFID tags. Fig.3 shows the data sources used to acquire contextual information. Different types of RFID tags are assigned to doctors, nurses, personnel and all necessary devices in the hospital.

The RFID module polls the reader periodically to get the list of RFID tags visible. The passive tags use the energy incident from the reader, to return their Electronic Product Code (EPC). Each reader reads the tags at its own internal

frequency. The readers are sampled every 2 s. If a tag is detected at least ten times in a 30 s window of time, then the tag is visible. However, if a tag goes undetected for 4 consecutive windows i.e. 120 s the tag is determined to have become invisible in the readers field of view.

Tag visibility rules1
If number of times tag seen ≥ 10 then
Event (Tag Visible)
If tag not seen for ≥ 120 s then
Event (Tag Invisible)

However, the identification data captured by an RFID reader normally does not have complete information about the object or activity associated with the object. In this pervasive hospital, the personnel and anything that is labeled with a tag, is identified by a number, and not by its exact name or type. The process of obtaining information associated with the ID (such as name of the device/drug/personnel, date of the manufacture, the expiration date, the permitted task by personnel, etc.) is defined as Data Processing. Data Processing is typically conducted by a software program called Middleware, which formats data.

As RFID tags must have a 64 bit cod, this code must have the ability to keep necessary information about the people or objects. In some cases that one tag is not sufficient, two or more tags are used.

The code in this scenario consists of at least the following fields:

a. Two bits are used for identifying the tag types (device tag, drug tag, personnel tag, or patient tag)

b. A 16 bit Serial Number which is a unique number of the item of the same type.

c. Depending on the tag type:

Personnel tag, 3 bits are used for public, private and isolated spaces. Each bit has the value of one, which means that the personnel are allowed to enter that space. 3 bits also are needed to identify the occupation of personnel.

Drug tag, 14 bits are necessary for company ID, expiration date and description about consumption.

Device tag, 14 bits are used for determining the ward that the device belongs to, and necessary comment for users, etc.

Patient tag, consists of one bit for sexuality, and 5 bits for unit ID (CCU, ICU, Surgical Unit, etc).

When one or more tag is visible by the reader, one or more application may be done, based on time and location of RFID tags and data processing that is discussed above (below).

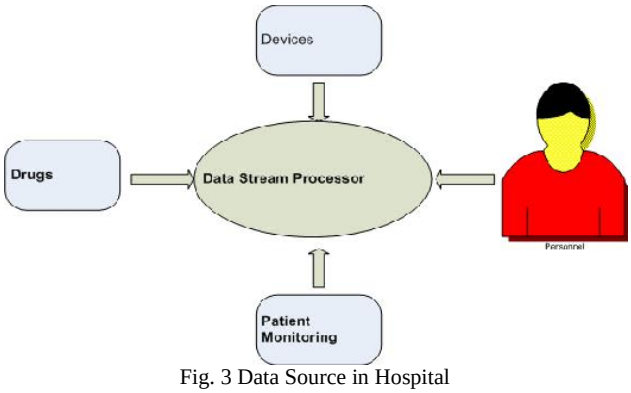

Fig. 3 Data Source in Hospital

B. Design and Implementation

To capture common features of RFID systems in the hospital, this section shows several RFID-based application scenarios and implementation some of them including: object finding, thing reminder, person location detection, auto downloading system and communication system, respectively.

In all implementation, an RF sender/receiver module attached to the computer is used in place of a reader.

Object Finding System: This system is supposed to be able to find an object or some objects in a room where RFID tags with ID codes and readers are placed. Some RFID tags are put under the floors in a pre-designed layout. Such a tag is named position tag that keeps a symbolic number, which is associated with the coordinates of the tag stored in a database. In one room, the RFID reader reads all RFID tags that are near it. The obtained tag IDs are sent to the database via the wireless LAN and then used in a location analysis process as shown in Fig. 4. If a tag attached to an object is read, the four surrounding position tag's coordinates determine the object's position coordinate. This system can process data to find a lost object.

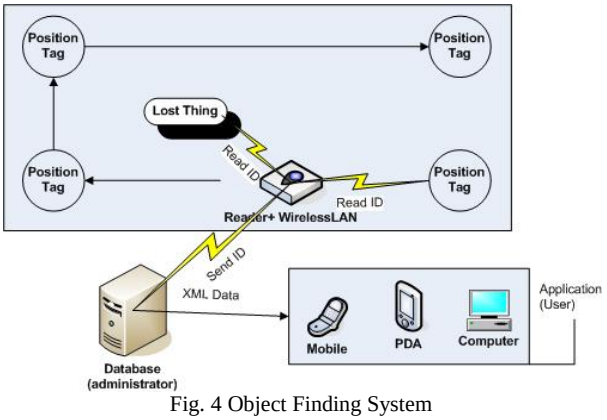

Fig. 4 Object Finding System

Reminder System This system is supposed to give a user advice messages in a room/house entrance when he/she forgets to take something with him/herself. The system requires that there is a RFID reader at an entrance; all things for a user to bring are attached to RFID tags, and the item IDs are input to the application in advance. When the user goes out, the reader at the entrance reads the user's identity tag and

the items' tags. These IDs are sent to a database via wireless LAN and then used in a process as shown in Fig. 5.

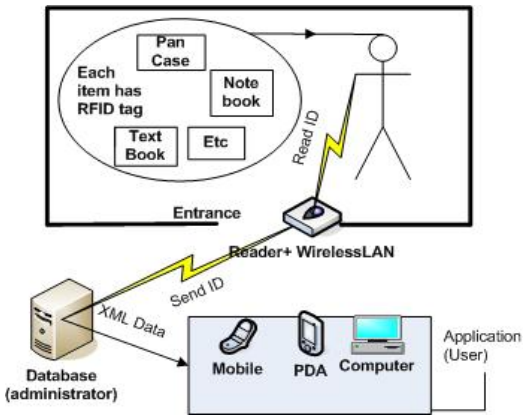

Fig. 5 Reminder System

The obtained ID data is compared with the ID data in the database that the user input beforehand. If there is unmatched ID data that remains in the user input ID data set, the application reminds the user in some way such as a speech message of "you forgot to take the desk pad".

Person Location Detection System: This system can get a person's location by detecting.

RFIDs carried with the person. The system requires one RFID tag per person and several RFID readers. Some RFID readers are buried under the floor in special places such as the entrance. The location data in XML format of RFID readers is stored in a database. If the person steps over a RFID reader, the reader reads the person's RFID tags and sends the IDs to the database via a wireless LAN that is connected with the reader. The tag IDs and RFID reader's locations are used to locate the person's position in the application as shown in Fig.6.

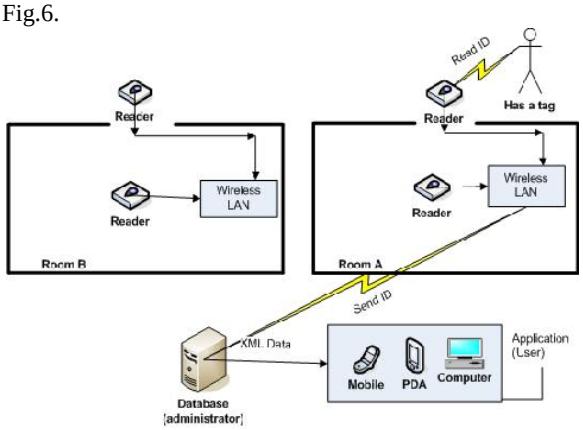

Fig. 6 Person Location Detection System

In our implementation when one of the personnel or patients is moving through the hospital, his/her tag is detected by the readers located in all parts. Each reader sends tag ID, Date, Time and location of itself to the central background system. This information is saved in a database named Following.

objDataAdapter.InsertCommand.CommandText = "INSERT INTO Following" + "([ID Number],[Date],[time],[location])" + "VALUES(@ID,@Date,@Time,@location)";

Imagine a computer in a particular location as a reader. When a person arrives adjacent to this computer, his/her unique ID is sent. This ID is received by an RF sender/resiever module attached to this computer. The name, the ID and date and time of the presence of that person is saved in Following database. This process is done for all persons and all locations in any time, and fills the following database, as is shown in Fig.7.

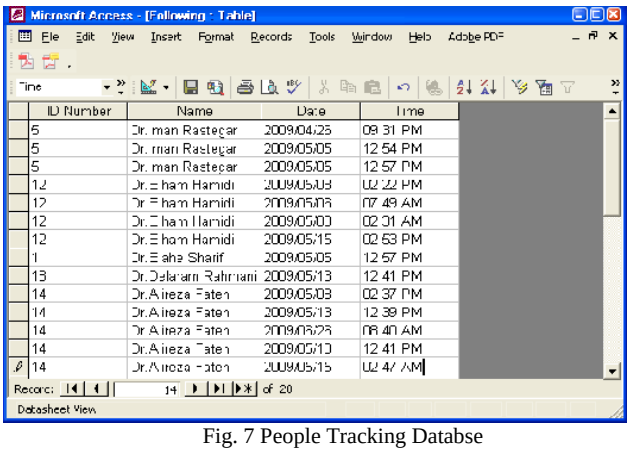

Fig. 7 People Tracking Databse

Auto Downloading System. This system is supposed to be able to download person's or any kind of information that is essential in a special situation without human request. For example when Dr.Fateh enters his room, the list of his patients, their personal properties, and their vital signs appear on the screen of his computer. Fig.8 shows patients of Dr.Fateh and their properties.

"SELECT AllpersonnelTable.Name,PatiantTable.UnitName,DoctorPatientTable.PatiantID,PatiantTable.PatiantName,PatiantTable.Age,PatiantTable.VitalSign" + " FROM PatiantTable INNER JOIN (AllpersonnelTable INNER JOIN DoctorPatientTable ON AllpersonnelTable.[ID Number] = DoctorPatientTable.IDNumber) ON PatiantTable.[Patiant ID] = DoctorPatientTable.PatiantID WHERE (AllpersonnelTable.[ID Number])=" + IDNumberof Dr + " ORDER BY PatiantTable.PatiantName"

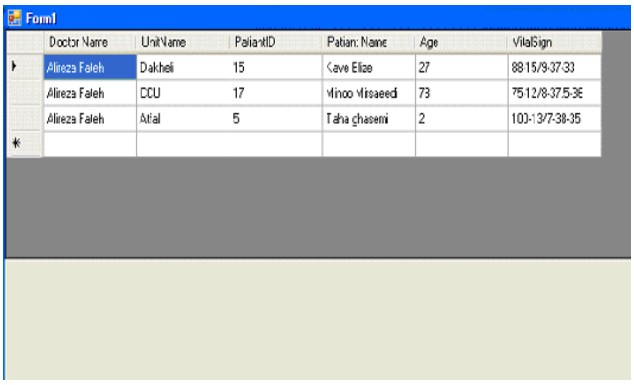

Fig. 8 Patients Auto Downloading of a Doctor

Communication System: The purpose of these systems is to provide communication between the system user and third parties. This system includes all the devices that help to communicate with another party, person or device like systems that provide simplified languages based on pictures or specialized computer interfaces. For example, when Dr.Fateh enters his /a patient room, and the history of his patients are auto downloaded on the computer, he can communicate with other hospital parts such as the laboratory via writing his orders and patient ID and pushing submit button as is shown in Fig.9. His orders are saved in the related database that can be seen in Fig.10 and is sent to that part with a sound alarm.

```
objDataAdapter.InsertCommand.CommandText = "INSERT
INTO LAB" + "([Patiant ID],[Date],[time],[Orders])" +
"VALUES(@PatiantID,@Date,@Time,@Lab)";
objDataAdapter.InsertCommand.Parameters.AddWithValue("
PatiantID",textBox7.Text);
objDataAdapter.InsertCommand.Parameters.AddWithValue("
@Name", textBox2.Text);
objDataAdapter.InsertCommand.Parameters.AddWithValue("
@Date", textBox5.Text);
objDataAdapter.InsertCommand.Parameters.AddWithValue("
@Time", textBox6.Text);
objDataAdapter.InsertCommand.Parameters.AddWithValue("
@Lab", textBox1.Text);
```

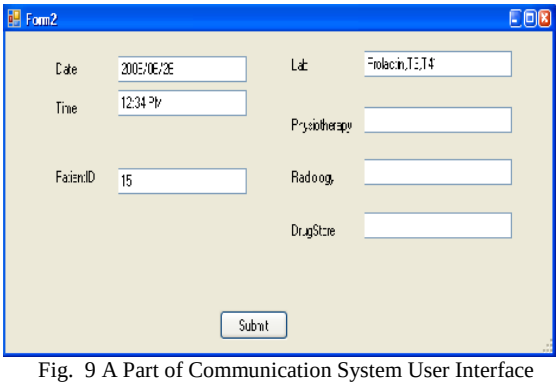

Fig. 9 A Part of Communication System User Interface

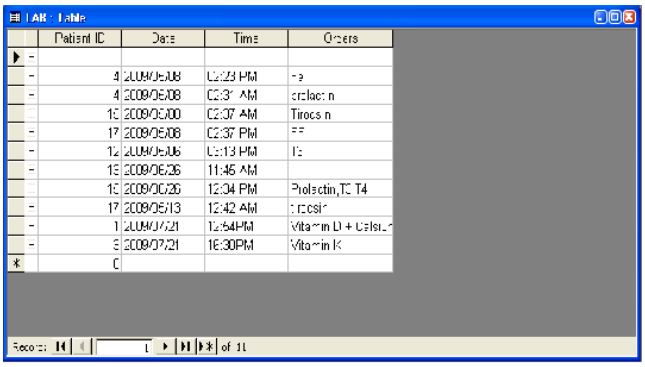

Fig. 10 Laboratory Database

IV. Conclusion

In this study, we presented a method of a context-aware system that analyzes data streams in a hospital. Our method uses technologies like radio frequency identification (RFID) to acquire contextual information about different items such as the usable objects resources and the staff locations in different parts of the hospital. The proposed method is implemented based on partitioning hospital into 3 different spaces; public spaces, private spaces and isolated spaces. Each of personnel RFID tag has three bits that show his/her entrance permission for three different spaces

References

[1] D. C. Deborah Estrin, K. Pister, and G. Sukhatme, "*Connecting the physical world with pervasive networks*," Pervasive Computing, IEEE, 1(1): 59–69, 2002.

[2] The Aware Home. Georgia Institute of Technology. [Online].2004,Available: http://www.awarehome.gatech.edu/.

[3] M. Perry, A. Dowdall, L. Lines, and K. Hone, "*Multimodal and ubiquitous computing systems: Supporting independent-living older users*," IEEE Trans. Inform. Technol. Biomed., 8(3): 258–270, 2004.

[4] F. Axisa, P. M. Schmitt, C. Gehin, G. Delhomme, E. McAdams, and A. Dittmar, "Flexible technologies and smart clothing for citizen medicine, home healthcare, and disease prevention," IEEE Trans. Inform.Technol. Biomed., 9(3):325–336, 2005.

[5] H. Kautz, L. Arnstein, G. Borriello, O. Etzioni, and D. Fox, "*An overview of the assisted cognition project*," Proceedings of workshop on Automation as Caregiver: The Role of Intelligent Technology in Elder Care, 2002.

[6] Evi Syukur and Seng W. Loke, " MHS Learning Services for Pervasive Campus invironments", IEEE International Conference on Pervasive Computing and Communications Workshops, 2006.

[7] Zhenmin Zhu, Xiaoli Su, "*A User-Centric Pervasive Computing Services Model for Medical and Healthcare*", IEEE International Conference on Grid and Cooperative Computing ,2007.

[8] Sheetal Agarwal, Anupam Joshi, "*A Pervasive Computing System for the Operating Room of the Future*", Springer Science + Bussiness Media, pp.215-228, 2007.

[9] Dorln Panescu, "*Healthcare Applications of RF Identifications*", IEEE Engineering in Medicine and Biology Magazine, pp.77-83, 2006.

[10] Zhenjiang Miao, Wei Su, " Pervasive *Computing BasedMultimodal Tele-home Healthcare System*" , Proceedings of the 27th Engineering in Medicine and Biology Conference, China, 2005.

[11] Fabrice Axisa, Pierre Michael Schmitt, Claudine Gehin, Georges Delhomme, Eric McAdams, and André Dittmar, "*Flexible Technologies and Smart Clothing for Citizen Medicine, Home Healthcare, and Disease Prevention*", IEEE Transactions on information thechnology in biomedicine, vol. 9, no. 3, 2005.

[12] Mahesh Subramanian, Ali Shaikh Ali: Omer h a , Alex Hardisty and Edward C. Conley, "*HealthcareQHome: Research Models for Patient-*

Centred Healthcare Services", IEEE International Symposium on Modern Computing, 2006.
[13] http://www.cnn.com/ Maryann Napoli, Preventing medical errors: A call to action. HealthFacts January 2000.
[14] http://www.cnn.com/ HEALTH/9911/29/medical.errors/, November 1999.
[15] Zhenjiang Miao, Baozong Yuan, "*Discussion on Pervasive Computing Paradigm*", IEEE Xplore. Restrictions apply, 2004.
[16] J .Riekki, T. Salminen ,I. Alakarppa, " *Requesting Pervasive Services by Touching RFID Tags*", IEEE Pervasive Computing, 20(5):45-52, 2006.
[17] S. L. Garfinkel, A. Juels and R .Pappu, "*RFID Privacy: An Overview of Problems and Proposed Solutions*", IEEE Security and Privacy Conference, 2005.
[18] Fusheng Wang, Shaorong Liu, Peiya Liu, and Yijian Bai, "*Bridging physical and virtual worlds*", Complex event processing for rfid data streams, In EDBT, 2006.