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Development of Embedded Personal Health Care Record System

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ABSTRACT

Various systems, methods and techniques are in use by patients and medical centers to provide the necessary information and to serve medical profession including hospital information systems. One of the most important services is Personal Health care Record (*PHR*) *portability and management. This problem has become out of history of paper records kept separately by physicians, clinics, hospitals, pharmacies, insurance companies and patients themselves. Many approaches were implemented to improve and manage the PHR including portability solution. These approaches were based on implementing portable memory device such as flash memory and Smart Cards. In this work an embedded PHR system was developed. The developed system allows operating and managing PHR by the help of standalone system.*

***Keywords*:** *Personal Health Care Record* (*PHR*), *Microcontroller Unit*, *Electronic Health Record* (*EHR*), *Health Care Information System, Patient System Operation, Clinical System Operation, Pharmacy System Operation, Pharmacy Web Service*

1. Introduction

Various types of technologies are in use by health care industry plays a vital role in improving patient-physician relationship [1].

Modern Information and communication technology have significantly changed the way of certain interactions between physicians and patients are performed and also have increased the ease of accessibility to health care providers' service.

The present evolutions of computer technology use modern facilities of interaction and communication, but a gap in information accessibility, availability, management and compatibility is still existed.

In spite of IT implementation in hospitalization and health recording system, the paper-based records are utilized in current health care setting resulting in rise medical errors.

Nowadays different systems are used in medical information industry to support the work of medical staff, data acquisition and processing, clinical management and electronic medical (or patient) records.

Although the aim of currently used systems is to provide service integration, but is still one of the main challenges for healthcare practitioners.

This challenge emerged from the usage of paper-based record which is held separately by physicians, clinics, hospitals, pharmacies, insurance companies and patients themselves.

Improvement of healthcare and clinical management systems including personal healthcare record is still considered as one of the most common IT activities. That is because the personal healthcare records have the potential to help individuals take a more active role in their health care by allowing them to access and coordinate personal health information and share it with those who need it.

Also the basic health information, such as demographic and health insurance information and lists of conditions, medications and allergies in PHR play the main key in medial diagnose and therapy [2].

This explains why researches and development in the field of health care and patient record is a viable continuous process.

The currently used PHR products are well-known as computer-based records. These products are classified according to carrier—processing devices which are used to carry out the problem of accessibility and portability of PHR. The PHR products are usually manufactured as a standalone product (e.g., accessible on the Internet or on a USB drive) or one that is integrated with the Pro-

vider's Electronic Health Record (EHR).

The aim of this work is to present an easy accessible and portable PHR with providing a robust and comprehensive support system based on embedded system design. In this case the design of embedded PHR includes integrated communication submoudles based on SMS, internet and Zigbee technologies to provide accessibility of the system.

In addition to that the work provides different methods to capture and access patient's medical records by the help of different communication media. In this scenario, a patient's medical record is stored in one geographical location on a server which is accessible from anywhere in the world via the internet.

2. Background

2.1. Health Care Information System

Information technology has implemented to deal with health care and to provide treatments for great number of medical conditions. In addition to that the process of computerization and automation plays a great role in health care practices. Besides the volume of information that is maintained for each patient has grown rapidly. As a result of this increase in information, it is often difficult for care staff to quickly find critical data about patient.

In clinical and hospital centers we can consider three types of informative parameters which needed to be considered in health care information system, mainly when we are talking about patient health care record [3], these types are:

1) Personal information: The hospital may want the name, address and the age of the patient. This type of information is necessary for personality recognition.

2) Patient's history: This type of information is needed by physician who may want to know the patient's history and recent vital sign data. In this case the diagnostic and therapy procedures are taken into account including the genetic background of the patient.

3) Health care services and support system: This type information is considered as: 1) Patients billing system which includes: insurance carrier, sponsors, medical provider, 2) Physical space requirement.

4) Healthcare giver: This type of information may be especially helpful for administrative, legal and judicial purposes to trace the process of medication taking into account the responsibility factor. Usually health care givers are hospital administration unit, nursing staff, physicians and other personals that are included in medication process.

2.2. Personal Health Record (PHR) Concept

A Personal Health Record (PHR) [2] is a specified record which is implemented in clinical practices and designed for a consumer. PHR usually includes data collected from different sources such as from health care providers, pharmacies, insures and the consumer. A typical PHR would provide summarized information about the patient [4]. A PHR typically includes information about:

- Medications.
- Allergies.
- Vaccinations.
- Illnesses.
- Laboratory and other test results.
- Surgeries and other procedures.

2.3. Classification of PHR

PHRs can be classified according to the platform by which they are delivered [5]. PHRs can be classified by the form of carrier material; in this case there are two classifications: paper-based PHR and Electronic PHR.

Table 1 shows the basic comparison between these types of PHRs.

In spite of that the majority of healthcare providers continue to use the traditional paper based records system. Nowadays PHR refers to a digital form record which could be integrated with the provider's electronic health record [6].

2.4. PHR Models

As mentioned above, there are two basic classes of PHRs: paper based PHR and Electronic PHR. The models of PHR are categorized under consideration of these classes.

Nowadays it is necessary to implement PHR models in health care management system [7,8]. The type of implemented PHR depend on the method of data entry, connectivity and availability. One of the popular models

Table 1. Basic comparison between two types of PHRs.

PHR Class Property	Paper-based PHR	Electronic based PHR
Availability	Hardcopy	Softcopy
Accessibility	Locally	Globally
Protection	Open	Secure
Update	Difficult	Easy
Storability	On paper	On electronic carrier media
Distribution	Centralized	Distribution

is standalone or free-standing PHRs which are often PC-based and require manual data entry to populate and update the record. These Standalone PHRs make the organization and storage of medical data very simple. The most common free-standing PHRs are either paper-based, personal computer-based, or enabled by an Internet application. In general one can say that standalone PHRs provide basic tools that help people collect, organize and store their health information [9].

The second type of PHR model is integrated, interconnected, or networked web-based PHRs. This type of PHR can be populated with patient's information from a variety of sources, including EHRs, insurance claims, pharmacy data and home diagnostics and can provide consumers as well as providers with a more complete view of relevant health information.

In medical practice, these models still implemented to realize the process of PHR formation. For example paper-based PHR are commonly used in developing countries but networked PHR are developed in some clinical centers where the integration of it is possible. However, surprisingly, it was noted in [10,11] that most health care institutions, including those in the United States, still maintain most of their patient's records in the form of paper charts. This scenario has rendered the almost impossible task of integrating and simultaneously managing patients' records across hospitals, clinics and between countries or states Full versions of interconnected PHRs have been not realized yet.

2.5. The Importance of PHR

Having relevant information available to patients for management of their medical conditions still one of the main problems in medical practice. Personal health records are important for patients, their physicians and the health care system [12]. In this section we will discuss why the PHRs are important?

- **PHRs are the empowerment of patients**: PHRs let patients verify the information in their medical record and monitor health data about themselves (very useful in chronic disease management). PHRs also provide scheduling reminders for health maintenance services.
- **PHRs improve patient-provider relationships:** PHRs improve communication between patients and clinicians, allow documentation of interactions with patients and convey timely explanations of test results.
- **PHRs increase patient safety:** PHRs provide drug alerts, help identify missed procedures and services and get important test results to patients rapidly. PHRs also give patients timely access to updated care plans.
- **PHRs improve the quality of care:** PHRs enable continuous, comprehensive care with better coordination between patients, physicians and other providers.
- **PHRs increase the efficient of care delivery**: PHRs help avoid duplicative testing and unnecessary services. They provide more efficient communication between patients and physicians (e.g., avoiding congested office phones).
- **PHRs give better safeguards on health information privacy:** By giving patients control of access to their records, PHRs offer more selectivity in sharing of personal health information. The PCASSO (Patient-centered Access to Secure Systems Online) study at the University of California-San Diego suggests that PHRs are more secure than paper records.

3. System Design

In this section we will discuss the proposed system, which consists of two applications: patient system clinical system and pharmacy system.

3.1. Patient System Operation

Figure 1 shows the block diagram of patient system block diagram. It consists of microcontroller unit, interfacing module, portable memory module, data commutation module, voice module and data input/output module which may be a touch screen.

The block diagram shows the microcontroller which plays the role of processing and controlling and it is also manages the other system blocks [13]. The interfacing module is a special designed hardware which allows connecting external devices into microcontroller unit. To store or read data of PHR a portable memory module is used. This module allows to connect USB flash memory or SD card to the system.

The data commutation circuit module consists of four types of data commutation submodules: SMS submoudle, internet submodule (WiFi or Zigbee), Ethernet submodule and GPS submodule.

To inform or alert end-user, an external device which is called Voice module is used. This module contains pre-recorded voice messages.

The data input/output module is a touch screen which

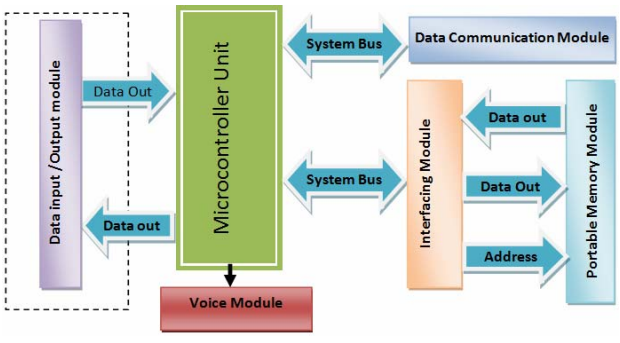

Figure 1. Patient System block diagram.

presented PHR data and can be use for data entry.

This system is designed to operate patient information. The information is operated by performing specific tasks. These tasks (**Table 2**) are selected by keys displayed on touch screen.

When user wants to make registration to clinical center or hospital he can press the Register key which browses two submenu items: registration mode and the nearby clinical center. By the help of registration mode menu item patient can select the type of hospitalization that he needs or cancel the operation. So firstly user may select the type of hospitalization and then pressing nearby clinical center which includes the clinical centers which provide the selected type of hospitalization.

The seeking of nearby clinical center is achieved by the help GPS technology. The GPS is used to determine the patient's location and the nearby clinical centers. As well as the clinical center is determined the SMS or internet message is to be sent to perform registration process.

The Emergency Call is an independent key which is a non-touch screen key. It is used in emergency situation when the user presses this key the GPS system determines the location of patient and SMS or internet message is sent to nearby emergency center.

The Browse key is necessary to read and update PHR. When this key is pressed two submenu items are displayed (read PHR and Update PHR). The end-user can read the currently existed PHR which is saved on portable memory device. This operation is usually done by physician or clinical service provider. The process of updating is realized by the help of SMS message or internet connection submodules which are included in data communication module.

To create or modify PHR the record key is used. In this case two submenu items are displayed. The submenu item create may be used for the first time to create PHR which will be stored on storage device and to be sent to related server. The submenu item modify is used to modify PHR record and the modified PHR will be also stored on storage device and to be sent into related server.

3.2. Clinical System Operation

The Clinic system shown in **Figure 2** provides support for routine activities of the healthcare professionals at the clinic. It maintains healthcare-related information, such as the physician's appointments, the patients that he/she has examined, notes related to the patients. Access to a patient's private information is restricted and secured, as discussed previously.

The Clinic system exposes Web server and Web service interfaces [14,15] for the clinic staff, the patients and the medical monitoring devices.

The Web server interface is intended for users who prefer to use a Web browser to access the e-healthcare services at the clinic. The Web service interface can be used by humans or devices to communicate with and deliver information to, the e-healthcare system. Applications that are implemented in Java use the Web service to communicate with the Clinic module.

The Clinic system allows a physician or a nurse to create and view a patient's profile and to add, delete and edit information (height, weight, blood pressure reading, temperature diagnosis) about the patient associated with the particular patient profile. The clinic server application runs as a Java servlet and provides Web pages for the physician and the patient to access via the Hypertext Transfer Protocol (HTTP) over the Internet. The patient information is stored in a database at the clinic, including the patient's profile, appointments related to the patient and prescriptions related to the patient. The clinic Web service communicates with the database over a wired or wireless local-area network using Java database connectivity.

The clinic Web service discovers information about the pharmacies in the area, augments the e-prescription with the name of the pharmacy to which the physician is to send the e-prescription and sends the e-prescription for the particular patient to the particular pharmacy using

Table 2. Main tasks.

Task	Description
Register	Pressing this key, user can register to nearby clinical center without passing the routing of registration.
Emergency call	This key is used in emergency situation
Browse	Pressing this key, user can browse PHR and update it.
Select	This key is used to select the task
↑ ← → ↓	Arrows are used to navigate the PHR and
Record	Pressing this key a keyboard is displayed on touch screen and the user can enter the data and modified patient record

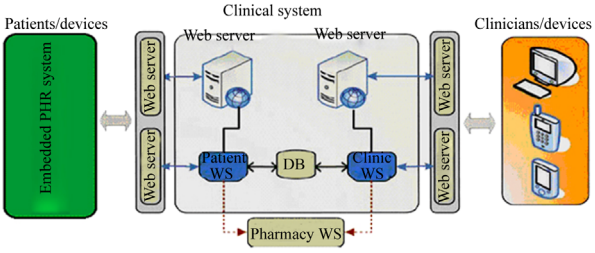

Figure 2. Block diagram of clinical system.

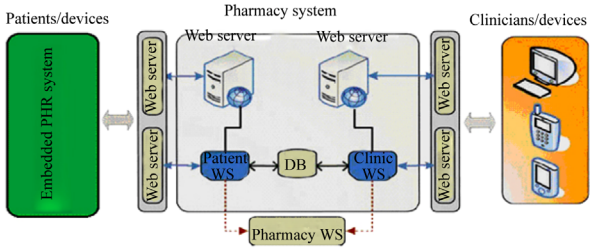

Figure 3. Block diagram of pharmacy system.

the Pharmacy Web service. To locate the pharmacy closest to the patient's home or the clinic, the clinic Web service uses the Yahoo! Local Search (Yahoo, 2007) Web service.

The physician can use the Web Server interface to access the e-healthcare system using a browser from a desktop/laptop computer or embedded PHR. The physician can use the embedded PHR system to enter/retrieve information about the patient during/after an appointment and access this information anytime, anywhere.

3.3. Pharmacy System Operation

The Pharmacy module is similar to clinical one but it serves pharmacy and this system is shown in **Figure 3**, exposes Web server and Web service interfaces.

The Web server interface allows the users to access the e-healthcare system at the pharmacy using a Web browser. The Web service interface provides access for applications deployed at the pharmacy and can also be used by humans and devices. The Pharmacy module provides services to the pharmacists, patients and devices used at the pharmacy. The Pharmacy module allows a pharmacist to view the outstanding e-pre-scriptions from the physicians and to view the e-prescriptions for a particular patient. The Pharmacy server application runs as a Java servlet and provides Web pages for the pharmacist, the physician and the patient to access via the Hypertext Transfer Protocol (HTTP) over the Internet. The e-prescriptions for the patient are stored in a database at the pharmacy for the pharmacist's and the patient's reference.

The pharmacy Web service communicates with the database over a wired or wireless local-area network using Java database connectivity. When the physician submits a new e-prescription to the pharmacy, the Clinic module communicates directly with the Pharmacy module over the Internet. Removing human intervention from the communication between the physician and the pharmacist and maintaining the information electronically, reduces the possibility of human errors.

The pharmacist can view the outstanding e-prescriptions for the patients, as the Pharmacy module receives them from the physicians. The Pharmacy Web service updates the status of the e-prescriptions as the pharmacist fills them.

When the pharmacist has filled an e-prescription, the Pharmacy Web service sends a notification to the Patient Web service. The patient can also determine, via the Web Server or Web service, whether an e-prescription has been filled and is ready for pick up or delivery. When the patient has collected the medication, the Pharmacy module sends an acknowledgement to the Clinic module, so that the physician knows that the patient now has the medication.

4. Conclusions

1) An embedded portable PHR stand alone system which can be implemented in clinical practice was developed.

2) It was shown that by the help of embedded technology, a design of a compact miniature PHR with modern commutation media support and internet facilities.

3) Using Embedded PHR in medical practice will provides complete support to patient and clinical staff.

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