A Mobile Phone SMS-Based System For Diabetes Self Management

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Abstract *This paper presents a mobile phone SMS-based system for self management of Diabetes. The system is designed to be a long term health companion for patients with diabetes. It allows the patients to get connected to their physician constantly. Through the exchange of SMS messages the patients send their insulin measurements, insulin intake and other data to the physician making continuous health monitoring possible. Based on the data sent, return SMS messages can be sent to motivate patients or to remind them of activities such as exercise and health care appointments. Offline mobile phone multimedia educational module is also included in the system. The system was tested in a clinic for a period of two weeks and results demonstrated both patient and physician satisfaction with the system.*

Keywords: *Mobile phone, Diabetes Management, SMS based system.*

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1. Introduction

One of the chronic illnesses where self management plays a crucial role for patient well-being is Diabetes mellitus type 1(DM1). Poor self management of this illness causes serious complications, which results in enormous health costs. The illness is due to destruction of the cells in pancreas which produce insulin and up to 10% of people with diabetes worldwide have this form of the disease [13]. Despite the relatively small percentage compared to the number of patients affected with the other form of diabetes (type 2 diabetes), developing computer/mobile applications or devices for DM1 diabetics is of special importance since the chances of complications are much higher. Based on visits to several physicians in the field no web or mobile applications that would connect physicians to their patients are currently utilized in the Palestinian Authority to assist in self management of this illness.

Conventional treatment of DM1 diabetics includes 2 or 3 daily injections of insulin given after obtaining glucose measurements. The patient writes down the measurements and injections every day in a special diary. Based on the diary the physician measures patient progress and adjusts treatment as necessary during regularly scheduled patient visits that occur several times per year [12]. This method has several disadvantages; first, it lacks the opportunity for timely interventions. This is important to avoid serious complication, for example, to immediately
detect trends in the data that require immediate action such as overnight hypoglycemia. Second, lack of motivation to complete a diary for a prolonged period of time makes it difficult to control the illness. These disadvantages necessitate the introduction of new methods and applications to assist diabetic patients.

The wide spread of mobile technology in today's society makes the mobile phone an attractive tool to provide more accessible and better health care. The mobile phone can be utilized as a diabetes self management tool to conduct a variety of tasks including recording and communicating patient measurements to the physician, receiving feed back through SMS messages, arranging for an appointment, educating the patient through offline multimedia mobile phone learning materials, etc. The development and evaluation of a mobile phone SMS -based application for DM1 patients that addresses these issues is presented next.

The remainder of this paper is organized as follows. In section 2 we survey relevant related work. We then present the results of requirement gathering in section 3. We present the architecture of our system in section 4. In section 5 we describe system functionality. We continue in section 6 to discuss the evaluation. We end with conclusions and present future work in section 7.

2. Related Work

A recent comprehensive review of diabetes terminal based applications is given in [9]. These applications vary in several aspects including targeted diabetes population (Type of diabetes), age group, terminals used (PDA, mobile phone, PC) and data input methods (manual or automatic). In automatic input methods a

meter transmits blood glucose data to mobile terminals automatically whereas manual input methods suggest entering data through a terminal keypad. Study results document positive feedback about the use of mobile terminals in diabetes self management as well as patient acceptance of application user interfaces. Also there is marked preference for using mobile terminals over PC.

Automatic wireless and wired input methods for entering blood glucose data have been adopted in several studies. While some of them indicate high patient acceptance [4, 7], others report difficulties in connecting the meter to the mobile terminal [1], and frequent failure in transmission [11]. Because of these conflicting results and the additional cost associated with purchasing special meter capable of getting connected to the terminal, this method was not suited to our needs.

With regard to wireless data transmission, two main technologies are used: GPRS and SMS. Several applications use either of these technologies or both to communicate the data between the patients and health care providers. GPRS systems allow the terminal to access Internet servers using HTTP or WAP protocols. One major disadvantage of these systems is the failure or difficulties in transmission from mobile phones to servers [2, 6, 8, 12] which led to data loss and patient dissatisfaction. Another disadvantage is the lack of knowledge of the Internet on the part of both patients and physicians [3]. On the contrary, systems based on SMS technology possess high reliability since it uses the store and forward transmission method. This allows the SMS messages to reach the server even if it was temporarily switched off or unavailable. Also diabetes systems are not data intensive; each patient needs to connect to the server to send/receive bytes of data only two to three times per day. The major disadvantage of SMS systems is cost when compared to GPRS systems but this is of importance for data intensive applications only.

In [5] special diabetes phones were distributed to the patients. The diabetes phone is a mobile phone with a device to measure blood glucose on site and the data is automatically transmitted to a web server. Despite its effectiveness, the high cost of such phones is a major barrier to clinical implementation.

An SMS based mobile system for diabetes control is proposed in [10]. It contains a decision support system to calculate insulin dosages based on food intake, exercise and blood glucose measurement. Despite its ease of use and power, it works only on mobile phones with the Windows mobile operating system which restricts its use significantly.

Based on the above discussion, from the technical point of view our aim is to develop a SMS based system that works on a wide spectrum of mobile phones and uses manual data input. The system was developed with active involvement of both patients and physicians as noted below.

3. Requirement gathering

Before any development of the system began, a consultative phase was initiated to investigate the problems with the existing management of diabetes and gather patient and physician impressions of the system concept. Meetings with 15 diabetes patients and three endocrinologists were held. From the sessions, the following conclusions were drawn:

- The idea of a mobile Diabetes system was viewed positively by both groups.
- Cost is of primary concern for both groups. Unless the cost of the system usage is low, it would not be attractive for long term use.
- All of the patients had mobile phones but the majority are not active mobile users and none of them had tried Internet access over the mobile phone. Also they stated that the Arabic interface of the potential application is preferable.

Based on the author's observations of the physicians' work, it was evident that they needed a simple but efficient system that would connect them with their patients. Since the majority of patients do not know much about their condition, the physicians recommended that the system serve as an educational tool as well.

4. System Architecture

The system follows the client server approach. Figure 1 shows the main components of the proposed system. The server side of the system consists of two modules: a Web module and SMS gateway. The client is a dedicated J2ME application that consists of two modules: core module and E-Learning module. Both the patient and the physicians can now start to communicate. The patients should send regular SMS messages containing their data to the server using their mobile application. These messages are received by the GSM modem. The physician can also start a communication through his Web interface and the gateway sending the patient an SMS; for example, to set an appointment to discuss data received or to discuss reasons for lack of data. It is important to note that on both sides, no immediate acknowledgement of receipt of an SMS message is conducted. This decision was made because of high reliability of SMS message delivery on one hand. On the other hand this would reduce the number of SMS messages exchanged and thus reduce cost on the part of both physicians and patients. A major advantage of this architecture is that the system can be set up quickly without the need to negotiate with the provider of communication services. Also different mobile providers' customers can serve as clients with the software installed. The following

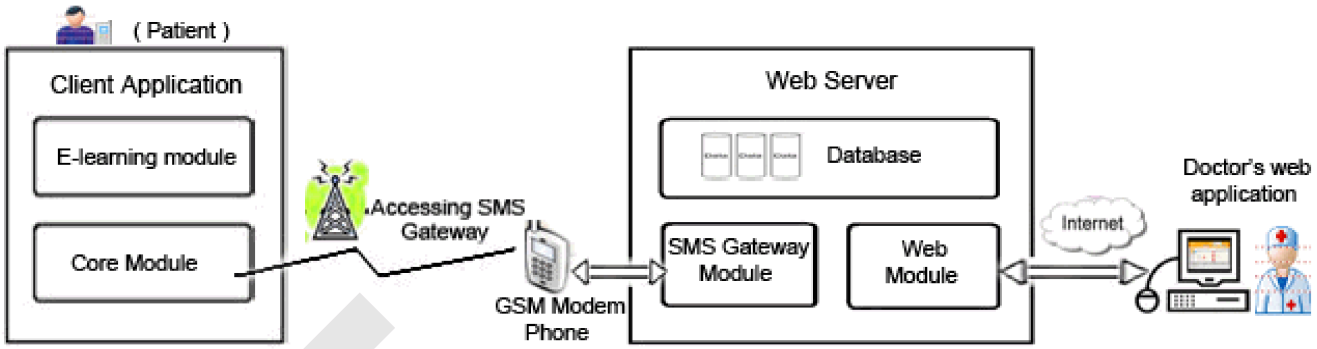

Figure 1. System Architecture.

subsections discuss the architecture in detail.

4.1. GSM Modem

GSM modem is a wireless modem that works with a wireless network. In order to utilize it a SIM card from a wireless carrier must be used. Through this device all communication between the client and server modules are conducted using SMS messages only. It must be connected to the server through Bluetooth or a cable. For a GSM modem, the Sony Ericsson w660i is used.

4.2. SMS Gateway

The SMS gateway is a light weight J2ME application that acts like a transit for SMS messages between the clients and the server. It checks all SMS messages received by the GSM modem and verifies its source phone number. If the message is generated by a registered client, the gateway checks the tag that the message starts with, analyses its content and stores it in the server database. Otherwise messages are discarded. Also the gateway controls sending back SMS messages from the physician's Web interface module to the client through the GSM modem. Every incoming message, after processing by the gateway, is deleted from the GSM modem. The software requires the mobile phone that operates as a GSM modem to support MIDP-2.0 with CLDC-1.0.

4.3. Web Module

This module is used by physicians only. It runs on the server and has access to the server database. The physician can access the Web interface locally or via the Internet. The module is constructed using PHP version 5.2.5 and the connected database using MYSQL.

4.4. Core Module

This module is responsible for generating SMS messages from patient inputs (Glucose level measurements, Insulin dosages, etc.) and sending it across the GSM network to the server database. Also it is responsible for receiving physician's messages and patient programs in the form of SMS messages, verifying the source phone number and format in order to be processed and stored on the patient mobile phone. For example, if the message contains the physicians' program the days and times of insulin measurement and insulin administration will be stored on the patient mobile phone to be viewed upon physician request. Incoming messages that correspond to the application activate this module that runs automatically to process them based on a tag that determines message content. In addition, the module contains an embedded alarm to remind the patient whenever he has to measure glucose level or take insulin doses. The alarm is set based on the physician's program and patient personal data such as meals times.

4.5. E-Learning Module

This module contains a set of off line educational multimedia materials about various aspects of the illness, including diet and exercise. These materials are displayed in form of text slides with audio. One important feature of this module is the patient's ability to search through the slides about any topic of interest through a specific interface. All the materials
are in Arabic. The slides are not hard wired and they can be easily expanded without the need to recompile the code. The text is presented in menu form with subject titles as menu items. The text of all slides is stored in a file where each title is followed by its corresponding subject. The narration of each title and subject is contained in a separate mp3 file. The module synchronizes the narration with the text displayed based on patient's selection. The technical issues such as scrolling and text division are performed dynamically based on the mobile phone screen size. Both the core and E-Learning modules are J2ME modules. These modules require the patients' mobile phones to support the same device profile and configuration as the SMS gateway.

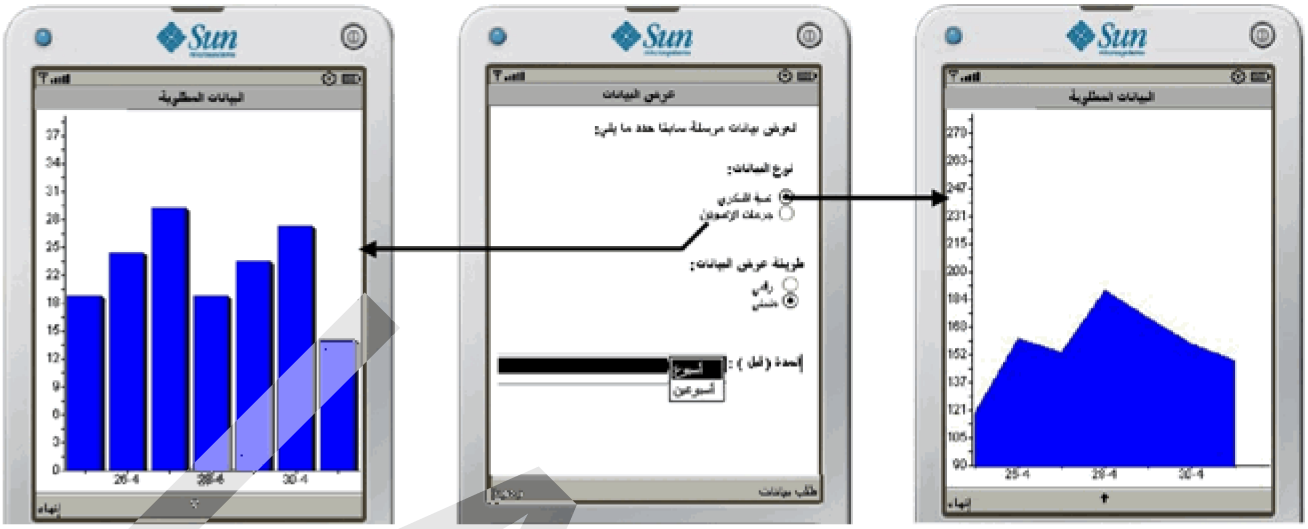

Figure 2. The patient is presented with options to select type of data to display, its form and period (center); insulin intake histogram sample (left); blood glucose measurement curve sample (right)

5. System Functionalities

5.1. Web Module

This module is intended to help the physician track his patients' health progress and guide them to maintain better health. Using this module the physician can manage patient accounts, view patient numeric data in the form of graphs or tables, and send different kinds of SMS messages that are intended to educate, motivate, warn and remind a patient about activities he should do like exercise, get regular checkups etc. This module also allows the physician to view patient messages, send patients a new program if required that would be automatically stored in the patient mobile phone. The user interface of this module and the client application are in Arabic.

5.2. Client application

This application runs on the patient's mobile phone and allows him to

- Send daily blood glucose measurements and insulin doses according to the physician program.
- Browse physician's programs which contains days and times of measurements and administering insulin. This program is saved on patients' mobile phones and can be changed by the physician and sent to the patient's mobile phone through SMS from the web application.
- Request and display previous measurements in both numeric and graphical ways representing maximum two weeks of data from the requested date.
- Send any important information to the physician such as requesting an appointment.
- Browse physician messages.
- Remind the patient to take insulin doses and perform glucose measurements according to the physician's program for the patient. The patient can change the time or frequency of the reminder if he wishes to do so.
- Browse multimedia educational material about diabetes and its therapy. The material is in the form of text and corresponding audio.

6. Evaluation

The System was tested in a diabetes clinic in the local area. Five patients with type 1 diabetes used the system for a period of two weeks along with their physician. During this period 220 incoming messages were sent to the physician, and 20 outgoing messages were sent back to the patients. In order to establish trust in the system by both patients and physicians and to ensure that SMS messages are not lost, the patients were asked to keep their paper diary for the testing period. At the end of the testing period, the content of the diaries exactly matched the messages stored in the database; thus, no incoming messages to the physicians were lost.

A training session for patients about use of the application was conducted over a 2 hour period. Four of the patients in the evaluation study were female and 1 was male. Interestingly, one female was using the system for her three years old diabetic son. Every patient was asked to try every feature of the system. Another training session was conducted for the physician over a 2 hour period that demonstrated how to create an account, view patient progress, send SMS messages, etc. By the end of the sessions both physician and patients were able to operate their applications.

The patients glycosylated hemoglobin (HbA1c) level mean was compared before and after the study. Despite the fact that the result show no significant

improvement to the medical condition of the patients, based on face-to-face interview, the patients reported satisfaction with the system because they felt connected to their physician during the entire study period; the embedded alarm reminded them when they forgot to do the measurements and messages were going in both direction giving a sense of security. For women, it was important that they could discuss their feelings in their SMS messages. The interview also revealed that the cost of exchanging SMS messages was not an issue for either physicians or patients.

Regarding the E-Learning part, the patients were impressed by the fact that they could easily reach the information about diabetes. They found the narration in the E-Learning module to be of special importance since it is possible to just listen to the material and not necessarily concentrate on the small mobile phone screen to read the corresponding text. Also they stated that that the amount of the educational material should be increased to cover more aspects of diabetes.

After the end of the testing period, the physician suggested a couple of improvements to the system. One improvement suggested was that the system should indicate the date of the last patient visit. This would prevent the possibility that a patient was not taken care of for a long time period of time especially as the number of patients grows. Another suggestion was that system should redirect to the physician's mobile phone SMS messages sent by the patients and tagged "Emergency" along with saving them in the database. Both these suggestions were implemented successfully.

These results showed that the system is very promising as a long term companion for diabetes patients, and further testing for a larger number of patients and for a longer period of time should be done in order to see how the use of the system would impact patients' medical conditions and consequently their health.

In adult patients with type 1 diabetes various mobile phone based systems improved patients' metabolic control (HbA1c) [5, 6, 10]. A group of 15 children with type 1 diabetes participated in a four month trial along with their parents [4]. This study reported that the system use was easily integrated as part of everyday life and showed potential as an aid in disease self management. Another study was conducted on 93 adults over a period of 9 months [1]. That study concluded that real-time transmission and feedback of information about blood glucose results is feasible and acceptable to patients.

7. Conclusion and future work

We have presented a simple mobile phone SMS-based system for the self management of diabetes. The system is very useful for long term type 1 diabetes self management where the patients feel connected to their physicians at all times which increases their sense of security. This sense of security is extremely important in caring for patients with chronic illnesses. In addition, initial testing proved system usefulness and feasibility. The system possesses high reliability and the cost of system setup and use is low. The next step would be to incorporate other elements of diabetes management into the system, including exercise and diet. Also long term testing on a greater number of patients is needed to investigate differences in health between patients using the system when compared to those who are not using it.

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