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MULTIFACETED E-HEALTH SYSTEM FOR MONITORING DIABETES PATIENT

[1]Olaniyi, O.M, [2]Omotosho, A., [3]Bashir, S.A, [4]Olaniyan, O.M, [5]Ojiakor, A.D,

[1]Department of Computer Engineering
[3]Department of Computer Science
[1,3]Federal University of Technology, Minna, Niger-State, Nigeria.
[2,4,5]Department of Computer Science and Technology
[2,4,5]Bells University of Technology, Ota , Ogun-State, Nigeria.
[1]engrolaniyi09@yahoo.com [2]bayotosho@gmail.com,
[3]bashirsulaimon@futmina.edu.ng, [4]tayoolaniyan2001@yahoo.com

ABSTRACT

Diabetes is the result of metabolic disorder in which a patient has high blood sugar either because the body does not produce enough insulin, or because cells do not respond to the insulin that is produced. Diabetes as a chronic disease require frequent monitoring in order to avoid complications. This paper presents the development of a multifaceted diabetes e- monitoring system which helps the patient monitor their sugar level without immediate presence of the doctor. Also, the system would be able to reduce the regular visitation of patient to physician. The results obtained from the evaluation of the designed system based on the implemented architecture shows that electronic monitoring of diabetes could provide an avenue to conduct remote monitoring in a convenient and faster manner both for the physician and the patient.

KEYWORDS:
-Health, diabetes monitoring, multifaceted system, glucometer.

1. INTRODUCTION

Information Technology has become a tool for improved and efficient medium for carrying out our daily activities. It has enabled efficiency and transformations in many areas like banking automation, education, government etc. One important area where ICT is beginning to make serious impact is electronic health (e-health), telemedicine, telemonitoring and related systems [11, 12, 13].

These systems are leveraging information technology infrastructure to provide healthcare to remote patients while at the same time reducing the cost, time and energy needed to provide qualitative healthcare by the care providers. The patients are also benefiting immensely form these systems. To further harness the benefits of e-health, we propose a multifaceted e-health system for diabetes monitoring in [11].

Diabetes is one of the chronic diseases that have taken life of many around the globe. According to World Health Organization 2011 report, diabetes is responsible for 5% of all deaths annually [1]. Its prevalence is also on the increase, the 2010 diabetes prevalence is 285 million people and expected to increase to 438 million by 2030 [2]. Given current projections, without urgent action, mortality due to diabetes is expected to increase by 50% in the next 10 years[1].

Diabetes being classified as a metabolism disorder is a group of metabolic disease in which a person has high blood sugar either because the body does not produce enough insulin, or because cells do not respond to the insulin that is produced, Most of what we eat is broken down into glucose and glucose is a form of sugar in the blood normally, when people eat, the pancreas automatically produces the right amount of insulin to move glucose from blood into cells, whereas in people with diabetes, the pancreas either produces little or no insulin, or the cells do not respond approximately to the insulin that is produced.

The problems associated with diabetes are numerous. These range from complications, to the cost of treatment, maintenance and dietary needs of diabetes patients. The serious health complications of diabetes include blindness, heart disease, kidney failure, weight loss, and poor healing of wound especially in feet. According to [3], a report of diabetes cost burden in five European Union (EU) countries (Italy, Germany, Spain, France and UK) indicates that the total direct annual cost ranges from €5.45bn (Spain) to €43.2bn (Germany) and the total direct cost burden of people with diabetes was €90 billion for 2010 estimates. These problems are more complicated in developing countries like Nigeria, where there is lack of government programme for the support and reduction of diabetes cases. The disease has caused lot of social problems in families where many had lost their breadwinners to the scourge of diabetes.

Telemonitoring is a medical practice that involves remotely monitoring patients who are not at the same location as the health care provider. In general, a patient will have a number of monitoring devices at home, and the results of these devices will be transmitted via telephone to the health care provider. Telemonitoring is a convenient way for patients to avoid travel and to perform some of the more basic work of healthcare for themselves [9].

Telemonitoring is basically patient approach and it is increasingly being used with chronic illness, supports timely transmission and remote interpretation of patients' data for follow up and preventive intervention [8].

The paper presents a multifaceted e-health system for the monitoring of diabetes which is capable of reducing problems associated with diabetes monitoring and follow-up to the minimum.The patient takes his/her glucose level using glucometer and send reports to health provider on regular basis. The provider examines the reading and gives medical advice to the patients. This system will definitely reduce the complications and cost associated with diabetes mellitus.

2. REVIEW OF RELATED WORKS

Authors in [8] reported that diabetes represents a chronic disease which is continuously growing worldwide, and they also observed that it can lead to complications and high expenditures only if it is closely monitored.

The global trend toward increasing rates of diabetes mellitus has raised concerns about the consequences and cost of associated morbidity and mortality in developing countries [12]. Developing countries, like Nigeria, are lacking in the utilization of monitoring facilities in health care especially for chronic disease like diabetes. The only avenue for diabetes treatment and management are still conducted in the traditional face-to-face consultation with the physician. Patients had to visit their doctors, take a test, and wait for results to be delivered. That process was

expensive, time-consuming, and inconvenient for all-involved. Having to get regular tests for this and other conditions is one of the factors that drive up medical costs. Such systems for assisting diabetes patients is the Supper Assist Project[4]. It implements a self care system for assisting users in managing their health. It has an electronic agenda that looks like a big board and which can be hanged into living room. The electronic agenda provide personal assistants to the patient of diabetes, e.g. motivation plan, consulting medical specialist and regular checkups.

Patients can send their glucometer readings online, access the online cookery book and a virtual personal trainer. Information stored in agenda is remotely accessible to the care givers. Super Assist project provides a good terminal to patients to assist them for diet, exercise, medication, time scheduling and their medical checkup. The limitation of the project is its non-portable. It is a big electronic board, which shows everything on the screen. Patient has to be in specific location (home or office) where the board is located to get assistance.

Another system called **M**ulti access services for telemetric **M**anagement of **D**iabetes **M**ellitus(M2DM), a European Commission's project that provides multi access services of tele-medicine to diabetes patients to improve the quality of their life by providing better communication means(web services, computer telephony interfaces) between residential and mobile diabetes patients and care providers. It can monitor and receive blood glucose data and pass it to an intelligent agent that triggers an alarm (i.e call a doctor), if there is any alarming condition [5,6].
The system is agent based. It utilizes rule-based , combination of statistic and model based techniques to process patient data through advanced methods for data analysis of aggregated blood glucose measurements and generate alarms automatically.

Authors in [7] report the development of m- health Open Source Platform for Diabetic Foot Ulcers Tele-consultations tagged "Sana". The system offers an end-to-end system that connects healthcare workers to medical experts. The systems runs on mobile smartphone that enables health workers to transmit medical files such as notes, audio and video to a central server for archiving, incorporation into an electronic medical record and reviewing by a remote specialist for real-time decision support. The main advantage of this system is that it is open source, its distribution is done under Berkeley Software Distribution - BSD license.

In [10], the authors identified the factors associated with monitoring glycaemic control among persons with diabetes in Benin City. Based on their findings, the authors recommended the inclusion of routine teaching of self-monitoring to diabetic persons in health educational talks. They also emphasized that Self-monitoring of glycaemic control is a cornerstone of diabetes care that can ensure patient participation in achieving and maintaining specific glycaemic targets.

Analysis of previous research in developing e-health platforms for diabetes monitoring reveals that most of the existing systems are not multifaceted. In addition, most of the systems are largely available in the developed countries. To improve and support health care provider's treatment of diabetes, our system provides a multifaceted approach for diabetes monitoring. The user can access the system hosted on the web server from either a mobile phone or a desktop or laptop computer from any location and at any time. This will significantly reduce the burden and time needed in face to face consultation and invariably reduce the cost burden of diabetes.

3. SYSTEM DESIGN

3.1 System Requirements for the Multifaceted E-Health System for Monitoring Diabetes Patient.

Considering the designed system from generic point of view, the following requirements are necessary: (a) **Eligibility and Authentication**: the system should be designed in a way that only

authorized patient should be allowed log in successfully. (b) **Reliability**: the system should work robustly without any loss of records as a result of the reliable database. (c) **Convenience**: patient should be able to login at any point in time. (d) **Availability:** the system should be available to the patient whenever they want to access it. The architectural requirements includes: (**a) ease of use**: the system should be easy to use without requiring users to memorize command, special terms or notation. (b) **scalability/reuse**: The proposed system should be extensible in order to upgrade the system by adding new features or modules without affecting the base modules. The hardware or software components of the system should be upgraded easily. The user characteristics of the designed system mandate that every user should be (**a)** able to test his/her blood glucose level before using the system. (b) Comfortable working with the computer

3.2 Infrastructural Model and Architect

i. **Overall System Architecture**

The multifaceted E-health systems have two main users: the patient and the physician. The physician has his/her own account and can perform functions such as viewing patients that have sent alerts, checking the database to confirm if the requesting patient is genuinely his/her patient and also checking the database to know the patient medical history. The patient has the ability to log in by inputting his/her user name and password, the patient can also input his/her blood glucose level and send to the physician.

In the designed system, registered patient been monitored would have the access code of a physician assigned to them during registration. The patient then inputs the readings of his/her blood glucose level, submit it via the electronic system which automatically sends alert to the physician application. The physician gets the alert, confirms the patient, compile his report which is then sent back to the patient. Figure 1 shows the system architecture of the diabetes e-monitoring system.

It consists of a centralized database server that stores all information about the patient requests. It is assumed that the user have tested his blood glucose level and found out that it is high or low.

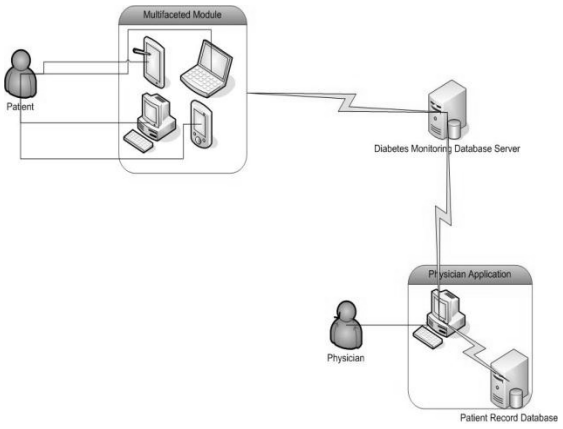

Figure 1 System Architecture of the Multifaceted E- Health System

Components of the Designed System

Multifaceted module

This module comprises of several user terminals/device such as mobile phone, laptop, tablets, desktop system through which they can access the diabetes application server. In order to do this, user needs to supply their authentication credentials, username and password which were given during registration process with the hosting hospital.

Diabetes Monitoring Server

Once the user logs into the application, the diabetes monitoring system becomes available to them for use. Through the multifaceted system, users can supply their blood glucose level through the analog/digital input interface provided by the system. The patient submits the reading which is automatically sent to the diabetes monitoring database server.

Physician Application

This allows the physician to access submitted request of patient from the diabetes monitoring database server for advice based on their blood glucose level. Here, physician needs to log into their application through username and password, as soon as their credential is verified on the system they are able to respond to the awaiting request by:

- Prescribing drugs to the patient to either boost the insulin sensitivity or boost the secretion of the insulin
- Advising the patient on diet, such as reducing the intake of unrefined sugar, cutting high carbohydrate diet and so on.

Patient Record Database

Patient record database contains the patient electronic health record. Every patient that submits request must have a matching health record and possibly past treatment histories in this hospital based patient health database before the physician can attend to their request.

ii. System Modeling

The model of the designed system was represented by building one or more graphical representation or description of a system. A formal model of the designed system was built using Unified Modeling Language (UML). In this paper, UML Use case diagram, Activity diagram, Sequence diagram were used to model the system.

The use case diagram of the e-diabetes monitoring system is shown in Figure 2. The use case diagram comprises two actors: Doctor and Patient. The Doctor has the privilege to register, login, view patients request, reply patient request and delete patient as well. The patient has the opportunity to register, login, send request to doctor and view doctors response.

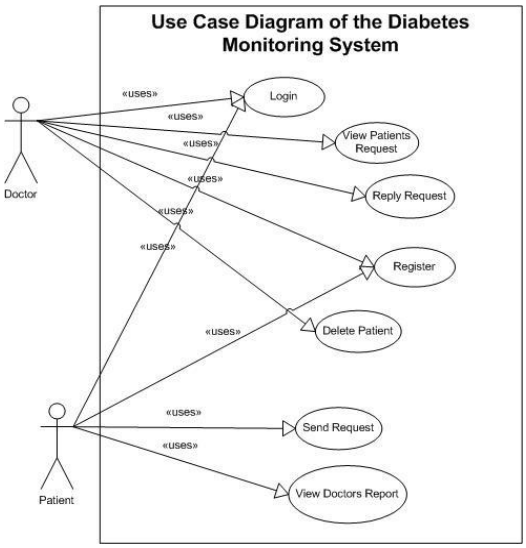

Figure 2: Use case diagram of Diabetes E-Monitoring System

The activity diagram shows the overall flow control in the designed system and this is shown in Figure 3.

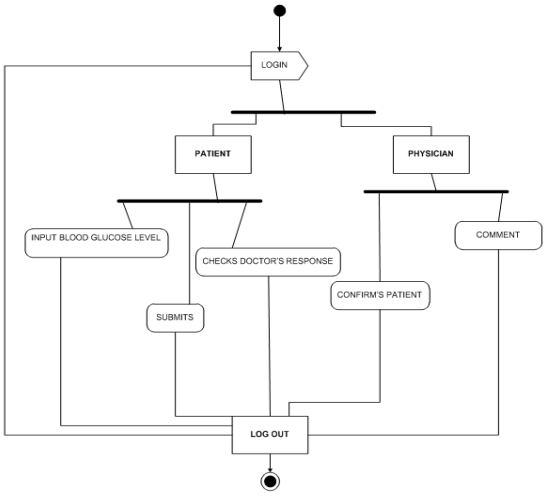

Figure 3: Activity diagram for patient registration

The sequence diagram in Figure 4 shows the communication between the patient and the physician that is, how patients login and input their blood glucose level with the physician response steps in the system.

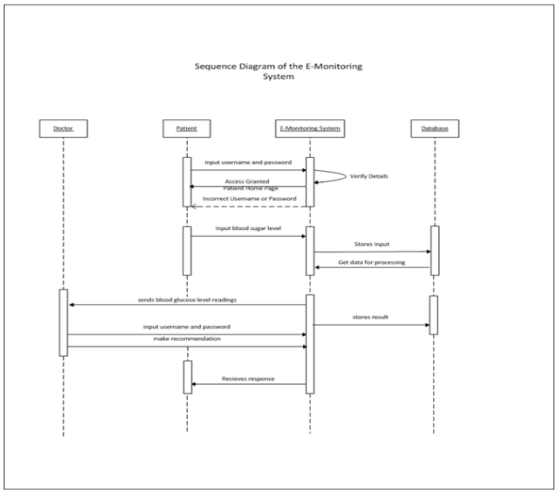

Figure 4: Sequence diagram for the E- Monitoring System

4.0 SYSTEM IMPLEMENTATION AND EVALUATION

The hypertext processor (PHP) embedded in HTML was used for the implementation of electronic web platform. The screen shot of the web for the multifaceted E-health system for monitoring diabetes patient system shown in figures as follows:

4.1 Login Page

Figure 5 is the first page on the system that allows only registered patients to login using their user name and password, for those who have not registered they have to click on “new user”. Figure 6 shows the mobile version on a live phone.

Figure 5 Login Page

Figure 6 Login Page

4.2 Diabetes Self Evaluation Page

Diabetes self evaluation system page in Figure 7 shows the patient's diabetes type, it also shows both the fasting period and after meal period ,all the patient needs to do is to transfer his/her blood glucose reading in to the system. The system provides an analog and digital interface for accepting patients' readings.

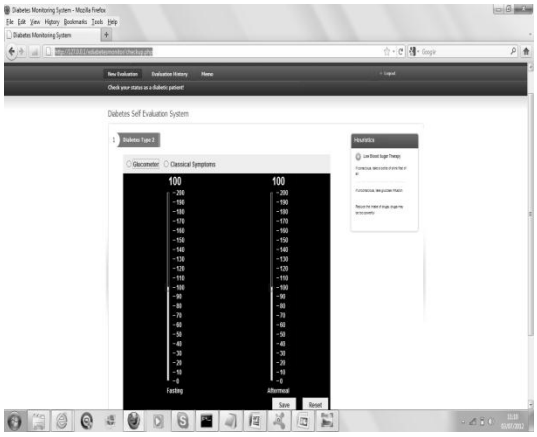

Figure 7 Diabetes self evaluation system page

Figure 8 Diabetes self evaluation system page

In Figure 8, after the blood glucose level has been selected, the patient click on save and a dialog pops up displaying ''glucometer readings successfully saved''. The saved reading is added to the patient profile and it is automatically sent to the remote doctor.

4.3 Patient's Evaluation History Page

Figure 9 shows the patient's evaluation history page, it consists of date the patient made request, the time, the test type, intensity- which is the reading for both fasting period and after meal and also doctor's response.

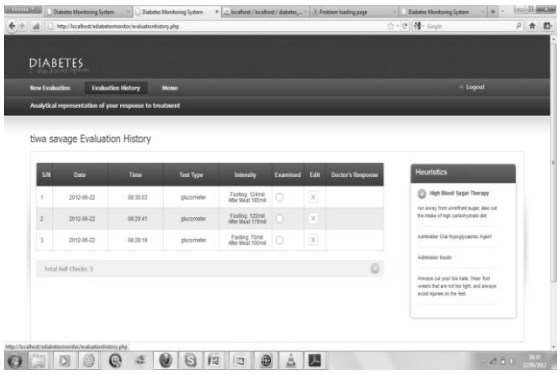

Figure 9 Patient evaluation history page

4.4 Diabetes Patient Examination Page

The diabetes patient examination page in Figure 10 shows a doctor's patients' requests list not yet attended to. Included in this request is the patient's identification data, the date and time the request- blood glucose readings-was sent. Figure 11 shows the mobile phone version.

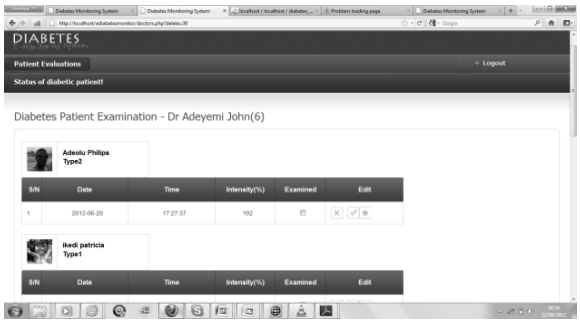

Figure 10 Doctor Diabetes patient examination page.

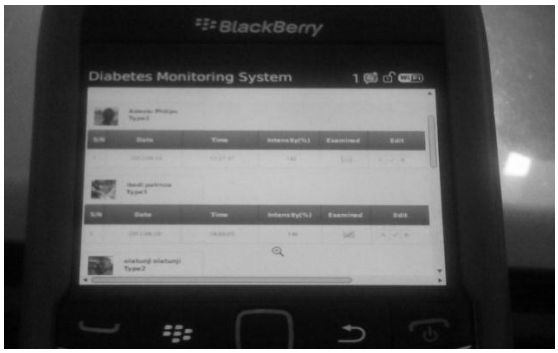

Figure 11 Doctors patient's evaluation page on a mobile phone

On the diabetes patient examination page, the doctor clicks on the evaluation button to make comments on an individual patient file. As shown in Figure 12, the doctor makes comments based on the blood glucose readings, after typing the message, he clicks on submit button to transmit the

report to the patient. Treated requests are marked as “examined” so the doctor can differentiates between pending requests.

Through the patient application, a patient can immediately view his or her doctors comment to the sent request as shown in Figure 13, the patient clicks the ‘’doctor’s response’’ button to view the doctors response.

Figure 12 Doctor Diabetes patient examination page

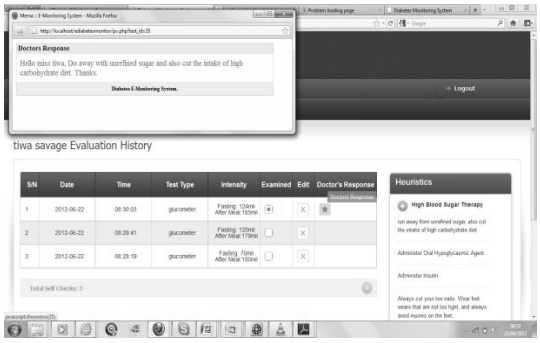

Figure 13 patient evaluation history page

System Evaluation

The performance evaluation of the designed system was carried out at Medicare Hospital, Ota, Nigeria. Evaluation was carried out by administering a questionnaire to five doctors, Table 4.1shows the average system rating against some of the important features of an electronic monitoring diabetes system. Where 5 indicates highest impact and 1 indicates lowest possible impact on diabetes monitoring.

Features evaluated includes: Promoting efficiency and quality improvement. Comprehensiveness and flexibility, User friendly, Easy to operate, Healthcare professionals having the ability to remotely review and better manage patient's blood sugar levels, Greater accuracy in reading and storing blood sugar level data by patients, it can be used anywhere there is access to network, It ensures security, Accessibility to patient record, Ability to monitor diabetic patient, and E-monitoring system Saves time of both the patient and physician.

s/no	Features of an electronic monitoring diabetes system.	5	4	3	2	1
1.	Promoting efficiency and quality improvement.		✓			
2.	Comprehensiveness and flexibility	✓				
3.	User friendly		✓			
4.	Easy to operate		✓			
5.	Healthcare professionals having the ability to remotely review and better manage patient's blood sugar levels	✓				
6.	Greater accuracy in reading and storing blood sugar level data by patients		✓			
7.	It can be used anywhere there is access to network	✓				
8.	It ensures security			✓		
9.	Accessibility to patient record.		✓			
10.	Ability to monitor diabetic patient		✓			
11.	E-monitoring system Saves time of both the patient and physician.		✓			

Table 4.1 Evaluation table of the e-monitoring system

5.1 Conclusion

The diabetes e-monitoring system designed in this paper has sought to make monitoring of diabetes patient easier. The Diabetes E-Monitoring System give the diabetes patient the opportunity to input their blood glucose readings remotely and the physician would advice them based on the readings .i.e. the patient should be able to monitor their disease even without the immediate presence of the physician and also the system should help reduce regular visitation of patient to the physician unlike the existing system which involves regular visitation of patient to physician. Future work should consider adding knowledge base to the system so that it can automatically respond and suggest possible solutions to patients.

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