

MOBILE SYSTEM FOR THE MANAGEMENT OF DIABETIC PATIENTS IN DEVELOPING COUNTRIES

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ABSTRACT

Mobile system for the management of diabetic patients is a technology that promises to help diabetic patients to manage their health conditions more conveniently. Though there are mobile systems that were developed for the management of diabetic patients, the systems did not capture local diets available in developing countries adequately. Hence, this paper presents a mobile system that addressed the aforementioned drawback. The developed system consists of a mobile application and a web-based application. The Mobile application was developed with JAVA programming language and SQLite database. A calorimeter was developed as part of the function of the mobile application using Rule-Based approach, also the Depth-First Search algorithm was used to retrieve foods. Effectiveness and users' perception are the two metrics used in system evaluation. The result from the evaluation of the developed system shows the effectiveness of 83.33% and Mean Users' perception of 94%. The implementation of the system in the healthcare procedures in developing countries promises to reduce the mortality rate in developing countries.

Key words: Diabetic patient, RESSMADIP, Food Search Engine, Mobile system, Management, Yoruba name.

1. INTRODUCTION

In recent time, the mobile device is receiving global acceptance because of its numerous advantages over desktop devices and changes the way information is accessed [1]. Mobile devices mobility is effortless and no extra burden on the carrier, and with more computational power than desktop computation [2]. According to [3], there are two (2) billion smartphone users worldwide and exponential increase of this figure in the coming years. The number of mobile phone users globally is projected to reach 4.68 billion in 2019 [4]. Portability of mobile phones was responsible for its highest demand in the market than other mobile devices such as Personal Digital Assistants (PDA), laptops, iPods and pads, etc. Apart from the use of mobile devices in banking and finance, social networking, entertainment, transportation, education, mobile devices are gaining prominence in delivering health care services [5]. The point of intersection between mobile technology and healthcare services is referred to as telemedicine [6].

Diabetes is a chronic disorder of glucose, protein and fat metabolism characterized by hyperglycaemia due to defect with insulin secretion, action or both [7]. There are two major types of diabetes, type 1 Diabetes mellitus (T1DM) and type 2 Diabetes Mellitus (T2DM). Whereas T1DM is due to absolute insulin deficiency, T2DM is due to relative insulin deficiency which is mainly due to insulin resistance [8]. In recent years, the prevalence of diabetes has increased exponentially in many parts of the world and the disease is now a worldwide public health problem [9]. The latest prevalence figure published by the International Diabetes Federation (IDF) revealed that 425 million persons are currently living with diabetes worldwide [10]. The total number of people with diabetes is projected to rise from 425 million in 2017 to 629 million by 2045[11].

There are many cases in which symptoms caused by high glucose levels in the blood do not appear immediately, and if systematic management is not provided, it leads to complications such as stroke, blindness, kidney disease, nerve damage, hearing loss, hypertension, sudden death, etc [12]. Therefore, diabetes patients need to manage their blood sugar constantly with diet control, exercise therapy, and medications. However, diabetes patients have difficulties managing it by themselves and they need constant management assistance and the help of their friends and family to maintain a lifestyle in which the diet is coordinated with exercise and activities. Therefore, there is a need for a system that helps them, in order to effectively allow control of the blood sugar of diabetes patients. Mobile computing has been identified as a technology that aids greatly communication and exchange of data and information, and it was utilized in the development of the system in this work.

This research used principles and techniques provided by mobile computing, and thereby help to improve the conditions of diabetics. A mobile application named RESMMADIP was used in this study to develop this service.

2. RELATED WORKS

Several works have been done on the management of diabetes mellitus by different researchers either by traditional way or the use of technology. [12] developed a mobile application to help diabetes patient manage their health conditions. The application classified the patient blood sugar level as either normal or abnormal or emergency. The patient with the normal condition are encouraged to maintain the state, the abnormal ones are to eat more, exercise more and take insulin, while a patient under the emergency case is to take rest. [13] developed a mobile phone SMS-Based System for diabetes self-management. The system used SMS as a mode of communication between diabetic patients and doctors. The patients sent their blood sugar level, insulin intake and other data to the doctors, and diabetic patients received feedback in form of motivation messages, warning and instructions via the same medium [13]. Another app for diabetes management is called “MySugr Logbook”. It is a friendly app for patients with diabetes to track their blood glucose level throughout the day. It encourages patient engagement through gamification mechanics, activities and rewards, and by using a ‘monster friend’ to represent their progress. MySugr Logbook benefits from multiple integration features, such as Apple Health, glucose meters, and the ability to sync data for export. The app is focused primarily on patients using insulin for diabetes management [14].

GlucOracle is an app from Columbia University Medical Center. It helps to forecast a person's blood sugar levels. Each meal submitted gives users a look at their projected glucose levels after the meal. This allows people to prevent spikes and crashes and to take insulin before they eat a meal. Its users can also get feedback about the nutrients in their meals to help them monitor and improve their food intake [15]. Glooko is a pay-to-use app for Android devices that is said to have a good reputation with users. It is designed to help people see how their diabetes impacts them, personally. It can display a number of key bits of information, including times of day blood sugar spikes or falls, days of the week diabetes has the biggest impact, how the user's blood sugar levels compared to other data. The built-in food database automatically tracks carbs, and graphs and trends can be viewed in multiple ways [15]. Review of the related works revealed the followings about most of the existing mobile application for the management of diabetic patients;

- The contents of the application do not contain local foods in a developing country like Nigeria.
- Some are concentrated on insulin -based diabetes management.
- Pay to use apps. Diabetes patients in developing countries as Nigeria find it difficult to pay for the use of such apps because the payments are in foreign currencies (USA Dollar, Pounds).
- Its lack of features that make the third party involved in the management of diabetic patients.

In view of the aforementioned drawbacks, this paper presents a system that addresses the aforementioned drawbacks.

3. RESEARCH METHODOLOGY

The methods and approach used in this work include; Research Approach, System flowchart, implementation and evaluation of the developed system.

3.1 Research Approach

The practical and theoretical approach was used. user-centred design (UCD) was adopted in this work. At the first stage, knowledge was elicited from health caregivers and literature on the management of diabetic patients. Multiple views of medical professionals were sought during a one-on-one interview, to acquire elaborate knowledge on the management of diabetic patients to enrich the knowledge-based on the system. The following set of professionals were interviewed; Endocrinologist, Nurses, and Dieticians. During this stage, diabetic patients and their relatives were interviewed to get firsthand information on the current challenges they were facing in the management of diabetes mellitus. The inputs from both medical professionals, diabetic patients and their relatives inform the features and functionalities of the developed system.

3.2 Architectural overview of the System

Figure 1 shows the architectural overview of the developed system. The system consists of four (4) units; Patient, Doctor, Patient Next-of-Kin (PNK), and Hospital units. The patient unit consists of the diabetic patient together with a smartphone. The mobile application built for the system runs on the mobile phone of the patient. The mobile application contains features and functionalities meant for the management of diabetic patients. Patient and a doctor can communicate either via call or SMS, and the data recorded on the mobile application is uploaded automatically to the online storage from time to time. The doctor unit designates a doctor with a mobile phone. The doctor gets either call or SMS from the patient's phone number and responds to him as needs arise. The doctor also has the privilege to check previous data of any patient in the online store for details information about such a patient. Such information can be used to guide patients on what to do or what not to do as pertains to the management of his health condition.

Patient-Next-of-Kin was introduced into the design because of the important role they played in the management of chronic disease like diabetes mellitus. The PNK received SMS from the patient during emergency cases such as Diabetic hyperosmolar state and the PNK can communicate via phone call to the patient. The diabetic hyperosmolar state usually occurs when the blood sugar level is above 600mg/dL [16]. The PNK receives SMS from the patient's phone number when the patient is in a state of any diabetic emergencies including hyperglycaemic crisis or hypoglycaemia. The hospital unit consists of a computer system which can be used to access patient's data from online storage. The online storage unit keeps the patient's data for ubiquitous access. With an internet connection, doctor and hospital unit members can access only data during patient visit to such hospital.



Figure 1: Architectural overview of the system.

3.3 The Use Case Diagram of the System

The use case diagram of the developed system is presented as shown in Figure 2 and the following are the activities that a patient can perform; login/logout, add information, view the information, call doctor, calculate calories needed in a day, search for calories in food, access diet plan and access exercise plan. The patient next-of-kin is able to perform the following activities; view information, call/SMS doctor, access diet plan, access exercise plan and login/logout. The doctor can do the following; Login/out, give instructions and give an appointment to patient.



Figure 2: The use case diagram for the system

3.4 Implementation

The mobile application of the system was developed using Java programming language and it runs on the Android operating system. The database of the system was designed using an SQLite database. The application runs on the Android operating system and tested on mobile smartphone with GPS enabled. The choice of Android OS is because it is open source and nonproprietary, and allows communication and interoperability with other devices.

3.5 Evaluation of the Developed System

The developed system was evaluated using effectiveness and usefulness as metrics.

- i. Effectiveness- Effectiveness refers to the extent to which the system behaves in the way that users expect it to and the ease of which users can use it to achieve their specific goals. Equation (1), equation (2) and equation (3) were used to Evaluate the Effectiveness of the system.

$$\% \text{Effectiveness} = \frac{\text{NCC}}{(\text{NCC} + \text{NWC})} * \frac{100}{1} \quad (1)$$

NCC = Number of Correct Calculation

NWC = Number of Wrong Calculation

$$\% \text{ Effectivene} = \left(\frac{\text{NFCF}}{\text{NFCF} + \text{NFWF}} * \frac{100}{1} \right) \quad (2)$$

NFCF = Number of Food Correctly Found

NFWF = Number of Food Wrongly Found

Combination of equations (1) and (2) results in equation (3)

$$\text{Total effectiveness} = \frac{\text{NCC}}{(\text{NCC} + \text{NWC})} * \frac{\text{NFCF}}{(\text{NFCF} + \text{NFWF})} * \frac{100}{1} \quad (3)$$

- ii. Usefulness- questionnaires were administered to health care professionals to access the mobile application for the management of diabetes patients and evaluate the application. The response is reported in section 4.3.

4. RESULT

In this section, the result obtained from the developed mobile system is captured and reported. The section includes; main features of the system, System's Performance Evaluation, and Users' Perception.

4.1 Main Features of the System

In the management of diabetic patients, the three aspects of patient's life that are very important and that must be taken into consideration at all-time are; food intake, exercise, and medications. And all the features and functions that help a patient in all the three aspects mentioned are included in the application of this mobile system.

Calorimeter

Part of the management measure for diabetes patient is to know the number of calories needed for a day activity. This helps in preventing obesity which research has shown is a risk factor for diabetes mellitus. The mobile application of the system contains calorimeter, which helps patients to determine the number of calories needed for a day's activity. With the knowledge of the number of calories needed a patient then determine the quantity of food to eat in adherent to the plate model. For example, a patient with the following input; age=34, Height=5.3 feet, weight=65kg, Sex=male, activity=moderate, requires 1, 869kilocalories per day.

An auto-search for food's calories (Food search Engine)

Once the amount of calories needed for a day activity has been determined through the use of calorimeter, the patient still needs to know the number of calories in each food type. With the auto search food calories of the application, patient search for the number of calories in any food item of choice. The auto search can be done using either the English name of the food or Yoruba name and the caloric value will be displayed. For example, food item yam or "Isu" is searched for and the caloric value is, for 100g of yam there are 116 calories. For 'Eko' which is pap in the English language, 1 teaspoon contains 91 calories. Figure 3, Figure 4, Figure 5 and Figure 6 show the results for the various searches respectively.

Sample Food Time Table

The mobile application also contains a sample Time Table for diabetes patient. Diabetes patient needs to know the number of calories needed for a day's activities. This information is needed to design the meal time table for their daily meal. The one on this application serves as a guide on how to design their own meal time table. Figure 7 shows a sample meal time table.

Exercise plan

The Exercise plan in the mobile application contains useful information on the different exercises that can help improve a diabetic patient’s health condition. Research has shown that exercise is one of the approaches to manage diabetes conditions effectively.

Medication plan

Medication is another means through which a diabetes condition can be managed. The mobile application developed contains useful information for diabetes patient on the aspect of medicine.

Spoon to Gram weight Converter

This converter is capable of converting a measure of a teaspoon to its corresponding weight and vice versa. The converter can convert either solid (particles) or liquid material. The user selects any of the two states before performing the conversion.

Online storage Center

The Online storage centre was developed for the storage of patient’s data and it is available for easy and timely access by hospital health workers during a normal hospital visit or during emergency cases. The name of the patient can be easily searched for, to retrieve the patient’s data as updated from the readings on the mobile application of the patient.

4.2 System Performance Evaluation

The effectiveness, which is one of the system evaluation metrics was examined.

Effectiveness

The following aspects of the system were used to determine the effectiveness of the system;

- [1] Calculation of patient’s calories-The system was used to calculate the number of calories needed by 30 users and the system was able to determine it correctly. Equation (1) was used to calculate the percentage effectiveness which is 100%.

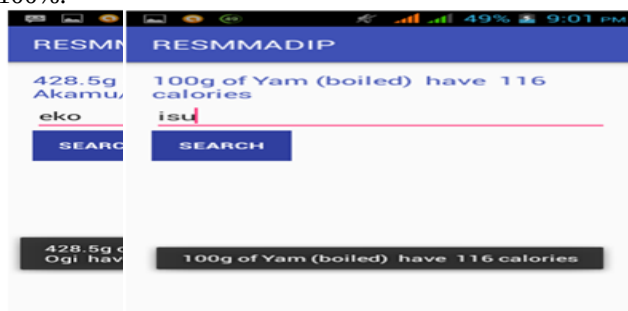


Figure 3: Interface showing the output of eko.

Figure 4: Interface showing the output of isu.

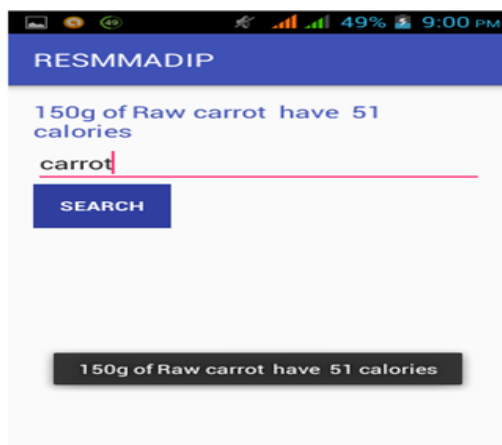


Figure 5: Interface showing the output of the carrot.

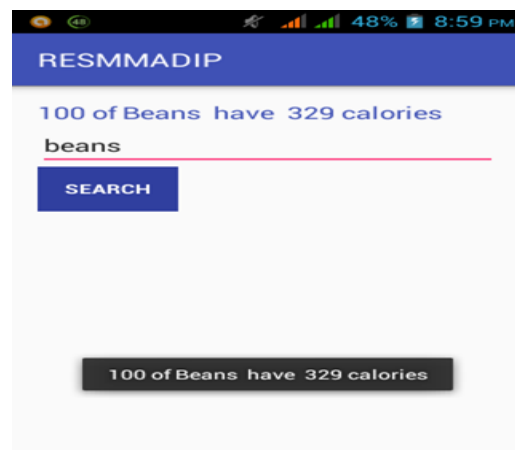


Figure 6: Interface showing the output of beans

Sample Food Timetable for Patients requiring 1500 calories								
BREAKFAST			LUNCH			DINNER		
Food Name	Qty.	Cal.	Food Name	Qty.	Cal.	Food Name	Qty.	Cal.
Rice	95.5g	125	Amala	35.5g	125	Beans	38g	125
Egg	1	17	Vegetable Soup	208g	250	Bread	2 slices	138
				2 cups				
Stew Pepper	100g	40	Skinless Chicken	57.4g	120	Tomatoes	1000g	180
Tomatoes	250g	45				Onions	100g	40
Onions	300g	120				Vegetable oil	3.3g	4
Carrot	400g	164						
Total		511			495			1493

Figure 7: The picture showing a sample food time table.

Searching of food calories

The calories of different food types were searched using the food search engine of the application in the developed system. The twenty (20) different foods were searched out of which eighteen (18) items were returned successfully, given 90% using equation (2). The overall percentage effectiveness of the system is calculated using equation (3) and is found to be 95%.

4.3 Users’ Perception

The following features and functionality of the developed system were examined by health care professionals as feedback to ascertain the level of acceptability of the system. A survey was conducted randomly for healthcare professionals in Oyo, Lagos and Ogun states of Nigeria and the outcome is presented in Table 1. The questionnaire was administered to fifty (50) respondents which is a convenient sample size based on the number of medical practitioners available for recruitment. Figure 8 is the pie chart, summarizing the output of the survey conducted on the users’ perception of the developed system. 88% of the respondents were favourable while 12% while unfavourable.

Table 1: Distribution of the respondents’ perception of mobile application

Item	Weighted mean score
The application is fast	4.02
The application is easy to use	3.88
The application can help reduce the health care cost	4.00
The interface is user-friendly	3.82
The application can help in reducing the number of patient in the hospital	3.50
Patient’s privacy is guaranteed	3.70

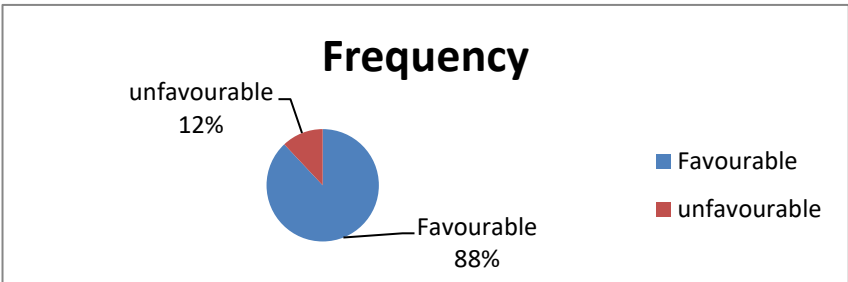


Figure 8: Chart of the users’ perception of the developed system.

5. CONCLUSION

This paper presented a mobile system for the management of diabetes patients in developing countries. The indigenous contents based on the application of the system making it more suitable for diabetic patients in a developing country like Nigeria than other available similar systems. The followings are the other features and functionality of the developed system, record of blood sugar level for offline and online retrieval, communication with doctors during critical cases, involvement of patient's next-of-kin in the management of diabetes patient, weight management features and functions. The application of the system is also educative as it contains information on different foods and the proper way of its intake, exercise tips, medications tips and guidelines. The system effectiveness is very high in performing its intended purpose and users' perception of the system was highly favourable in comparison with the other system they have used before. The system can be used both in hospitals and at home of diabetic patients for the management of their health conditions. This system is capable of reducing the mortality rate due to ignorant on the management of diabetes mellitus in developing countries with educative features of the system.

6. REFERENCES

- [1] Franklin, T., Sexton, C., Lu, Y. & Ma, H. (2007). PDAs in Teacher Education: A Case Study Examining Mobile Technology Integration. *Journal of Technology and Teacher Education*, 15(1), 39-57. Waynesville, NC USA: Society for Information Technology & Teacher Education. Retrieved April from <https://www.learntechlib.org/primary/p/6207/>. Accessed on 23 April, 2019.
- [2] B'Far, R., and Fielding, R. (2005). *Mobile computing principles*. Cambridge [England]: Cambridge University Press.
- [3] ICT Facts and Figures – The world in 2015. (2016). ITU. from <http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx>. Accessed on 15 Marh, 2016.
- [4] Statista. (2019). Number of mobile phone users worldwide 2015-2020 | Statista. [online] Available at: <https://www.statista.com/statistics/274774/forecast-of-mobile-phone-users-worldwide/>. Accessed on 23 Apr. 2019.
- [5] Islam, R., Islam, R. and Mazumder, T. (2019). *Mobile Application and Its Global Impact*. [online] Citeseerx.ist.psu.edu. Available at <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.295.7161&rep=rep1&type=pdf>. Accessed 23 Apr. 2019.
- [6] Wootton, R. (2001). Recent advances: Telemedicine. *BMJ*, 323(7312), pp.557-560.
- [7] Ayu, M.A., Ahmad, B.I. (2013). A framework of remote diabetes monitoring system for developing countries. Intelligent Environment Research Group, Kulliyah of Information & communication Technology (KICT), International Islamic University, Malaysia (ITUM). ISBN:978-0-9853483-5-9.
- [8] Isley, W., and Molitch, M. (2017). Type 1 Diabetes. Retrieved from <https://academic.oup.com/jcem/article/90/1/E2/2835608/Type-1-Diabetes>. Accessed on 10 August, 2017.
- [9] William, R., Clement, B., Yasemin, A., Erin, B. and Shannon, K. (2018). [online] Altfutures.org. Available at: <http://www.altfutures.org/wp-content/uploads/2016/04/Diabetes-2030-Population-Health-Management-2016-pop.2015.0181.pdf>. Accessed on 27 Nov. 2018.
- [10] Idf.org. (2019). *IDF Diabetes Atlas*. [online] Available at: <https://www.idf.org/e-library/epidemiology-research/diabetes-atlas/134-idf-diabetes-atlas-8th-edition.html>. Accessed on 12 April, 2019.
- [11] Idf.org. (2019). *International Diabetes Federation - World Diabetes Day 2018-19*. [online] Available at: <https://www.idf.org/e-library/epidemiology-research/54-our-activities/455-world-diabetes-day-2018-19.html>. Accessed on 11 April, 2019.
- [12] Lee, M., Gatton, T., & Lee, K. (2010). A Monitoring and Advisory System for Diabetes Patient Management Using a Rule-Based Method and KNN. *Sensors*, 10(4), 3934-3953. Retrieved from <http://dx.doi.org/10.3390/s100403934> Accessed March 16, 2016.
- [13] Salameh, O. (2012). A mobile phone SMS-Based System for diabetes self management. In *Journal of International Arab Journal of e-Technology*; Vol. 2, No. 3. Pp. 161-166.
- [14] Scott, J. (2017). The new mySugr Logbook 3.0 is here!. mySugr. Retrieved from <https://mysugr.com/the-new-mysugr-logbook-3-0/>. Accessed on 17 August, 2017.

- [15] Johnson, J. (2017). Best diabetes apps of 2017. Medical News Today. Retrieved from <http://www.medicalnewstoday.com/articles/317364.php>. accessed August 17, 2017.
- [16] Mayo Clinic. (2019). Diabetic coma - Symptoms and causes. [online] Available at: <https://www.mayoclinic.org/diseases-conditions/diabetic-coma/symptoms-causes/syc-20371475> [Accessed 12 Apr. 2019].

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