Research Journal of Applied Sciences, Engineering and Technology 7(22): 4661-4670, 2014
DOI:10.19026/rjaset.7.849
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: August 24, 2013 Accepted: September 17, 2013 Published: June 10, 2014

Research Article

DAS: Personal Diabetes Management System

Aisha Batool, Muhammad Habib ur Rehman, Kashif Ayyub and Wasif Nisar
Department of Computer Science, COMSATS Institute of Information Technology, Wah Cantt, Pakistan

Abstract: In this study we have presented the design and implementation of a Diabetes Assistant System (DAS) which is able to store and manage the diabetic patient's medical data. DAS (Diabetes Assistance System) is developed after studying several well-known existing diabetes management systems and includes many features that were not available in past. In addition to this many features of existing systems are redesigned for more productivity and effective disease management. DAS not only facilitates diabetic patients to manage their lifestyles but it also provides functionalities for medical practitioners and support staff for disease management features. DAS supports core features of user management, disease management, visit management and extended features for socialization. DAS is developed by focusing users' needs of mobility and ease of access hence available as web-based and mobile-based diabetes management system. DAS enables doctors to support patients remotely and view their disease history. Moreover, a doctor can manage his/her personal profile and daily schedule of online availability. Patients can manage their profiles, daily activities, test results, medications, foods intakes and appointments. In addition to this, patients can view their disease history, doctor's schedule and health tips. The support staff manages disease related information like medicines, manufacturers, tests, foods and exercises data. In addition they can view/manage doctor's schedule and appointments.

Keywords: Awareness, exercises, foods, medication, tests

INTRODUCTION

Diabetes is a chronic disease in which human body stops the production of insulin, produces insufficient insulin or has the high resistance of this hormone. Insulin is the hormone that controls the level of the blood glucose in the human body. According to the world health organization's prediction; diabetic patients would be 366 million in all over the world in 2013.The good BG level management can reduce the late complexities in the patient like heart disease, foot worm, eye sight problems and kidney failure etc. To manage diabetes effectively, accurate communication between the patient and the physician is necessary. For self management of diabetic patients, it is necessary to keep record of BG level, diet, medications, insulin inserted and exercise etc. It is stated by the American Diabetes Association that the patients suffering type-1 diabetes should monitor their BG level at least three times in a day and the clinically necessary as possible for the patients of type-2. The estimated death toll by diabetes in 2005 is 1.1 million people. Proper management of diabetes requires regular monitoring of BG level as well as consultation with the physician. This makes diabetes treatment expensive and difficult.

Mobile devices are the most common communication devices these days. The mobility and cost effectiveness of these devices enable the patients to take advantage and persistently connect with physicians. Web applications for the diabetes management are also useful as the communication between the patient and doctor is possible and patient's history can be managed remotely. The small memory and short screen are important issues with mobile apps.

LITERATURE REVIEW

Fuchao (2011) developed a health care system for diabetic patients to easily record the daily readings and also keep track of long term disease history. Patient's conditions are monitored using Wearable sensors. This system facilitates patients to find out all the nearest hospitals using Google map.

Mobile DMS was proposed by Brian (2011) has a user centered design. The main features of this project were online social network, a website and server. The server collects the data from the mobile devices, online social network and from the website. This system was assumed to be easily available and accessible to the diabetic patients at low cost.

Diabetes E-Management System was proposed by Lutes *et al*. (2006). The main feature is the ability of sending the user data quickly to the central server for effective patient management. Three applications

Corresponding Author: Aisha Batool, Department of Computer Science, COMSATS Institute of Information Technology, Wah Cantt, Pakistan

Table 1: Comparison table

DMS by	Glucose	Exercise	Diet	Medicine	Mobile	Web
Fuchao (2011)	Yes	Yes	Yes	Yes	Yes	Yes
Brian (2011)	Yes	Yes	Yes	No	Yes	Yes
Lutes *et al*. (2006)	Yes	Yes	Yes	Yes	Yes	Yes
Park *et al*. (2005)	Yes	Yes	Yes	-	Yes	No
Rudi and Celler (2006)	Yes	Yes	Yes	Yes	No	Yes
Osama (2012)	Yes	No	No	No	Yes	-
Vigersky *et al*. (2003)	Yes	No	No	Yes	Yes	-
Abrahams (2010)	Yes	Yes	Yes	Yes	Yes	Yes

developed for the DEMS system are; First, mobile application is of primary use that facilitates the user to record the entries to the central server; Second, monitoring application to monitor the patient's medication, diet, exercise; Third, web application that provides the same features that are available on mobile application (Lutes *et al*., 2006). PDA Based Point of Care PDMS was developed by Park *et al*. (2005) to facilitate diabetic patients in self management of their disease. The system lacks the communication between Patient and Doctor. PDMS provide the mobility and is able to predict the changes in body weight. ETS for Diabetes Management at Home was proposed by Rudi and Celler (2006) and provide regular online monitoring and also the offline diabetes management. For this purpose system integrated two technologies; Telemedicine and Rule based expert system. ETS allows patient to enter view history (Rudi and Celler, 2006). ETS calculate the GI (Glucemic Index) to measure the quality of food and provides recommendations about insulin and food etc. ETS can be used online and Offline but it doesn't provide mobility.

Mobile Phone SMS based DMS, proposed by Osama (2012), is a very simple and cheaper DMS with Arabic GUI. The system provides the communication between patient and doctor. Patient sends his/her Blood Glucose level and insulin intakes to the doctor through system and can take appointment (Osama, 2012). The system gives reminders to patient about insulin doses and glucose measurement as suggested by the doctor. System provides the functionality of changing the number of reminders as per user's choice. Another notable feature of the system is the provision of educational material, which is in the form of text and audio as well (Osama, 2012).

DMCS (Vigersky *et al*., 2003) permits the perfect determination of insulin dosage. When the information is entered the system starts the calculation on the information to calculate the insulin dosage but the patient can also select alternative dose of insulin (Vigersky *et al*., 2003). The data is presented in the form of graphical and tabular forms on the http//:www. Health Sentry. Net. E-Health Diabetes Management System is a typical DMS (Abrahams, 2010) which have three parts; Mobile diary application, Mobile social networking and Website interface. The mobile diary contains blood glucose, diet, medication, exercise, mood, weight record facilities. According to these entries website produce the graph of these data

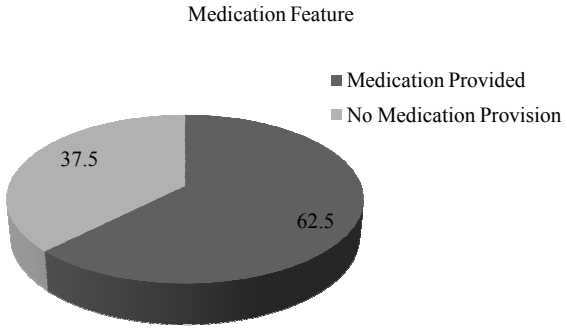


Fig. 1: Medication features in existing systems

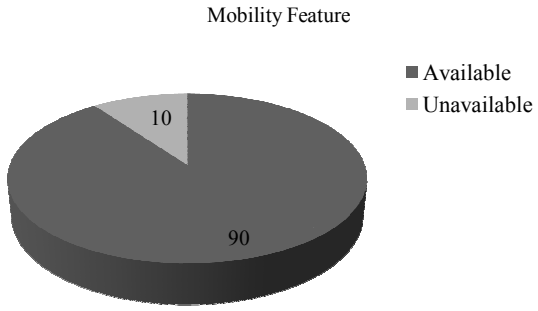


Fig. 2: Mobility features in existing systems

entries and more useful feedback (Abrahams, 2010). The social network contains the inbox that serves as mail box which receives the patient's private messages, forum to create the public posts, user profiles so that user can view other user's profile and privacy settings to decide and set their privacy if other users can view their profile or not (Abrahams, 2010). Table 1 summarizes the features provided by the systems that are discussed earlier. Almost all systems are providing mobility feature, but medication and diet management are still not provided by most of the systems.

According to the study of existing systems (Fig. 1) it is concluded that 62.5% systems provide medication feature, while 37.5% systems doesn't. Medication feature may include the management of patient's medicine history that which medicine is taken by the patient etc. This is useful for the doctor to suggest medicine in future. So it is needed to increase the percentage of medication feature in diabetes management systems.

In Fig. 2 a pie chart is used to represent the percentage of mobility feature on the basis of existing system's study. It shows that 90% of the systems provide mobility feature in their systems. And only 10% systems are not available on mobile phones. It shows the importance and need of mobile app, so that the patient can use system anywhere outside the home.

METHODOLOGY

Problem statement: Diabetes is the top 7th in life-threatening diseases. The diabetic patients not only need a continuous monitoring and diagnosis system but also require a state-of-the-art communication system between Patients and Doctors. The treatment of diabetes patients require regular checkups, frequent advises by doctor, a calculated medication, properly monitoring patient health, a balance of diet and exercises and proper education of how to fight with the disease. Therefore, a DMS is required that not only provide the said features but also provide some additional functionalities relating socializing, mobility, easy to access and cost effectiveness.

Proposed solution: Keeping in view the importance of Diabetes Management Systems, a new DMS is being proposed that will narrow the communication gap between doctor and patient at one end and manage the diabetic lifestyle at other end. The proposed system (DAS) is software that is helpful to manage diabetes while staying at home. The proposed system provides the management of diet, exercise, medication, tests etc. The main aspects of the system are online website and mobile application. Mobile application provides mobility feature that is of great importance as the mobile usage is increasing day by day.

Figure 3 is the use case diagram of the system which shows the behavior of the system. There are three actors in DAS which includes doctor, patient and staff member. Actors enter to the system by using login feature and they can add, delete and edit their personal profiles. Flow of data and communication between actors is clearly shown in the diagram.

System architecture: The Physical architecture of the system is a 3-tier architecture. Every tier encapsulates different hardware and software. These three tiers are DB server, Web server and End-Users.

Database server is responsible for the storage, retrieval and manipulation of data. It provides schema for backend database and ensure that all transaction on the server are performed according to ACID properties. In addition to this, the DB server is responsible for replication, backup and restoration of data. The DB server is also responsible for query optimization, fast retrieval and consistency of data.

Web server encapsulates application logic and business rules. It is responsible for the access of data from DB Server. The web server decides that which data should be accessed and when to access. Direct Interaction between end user and the DB server is not

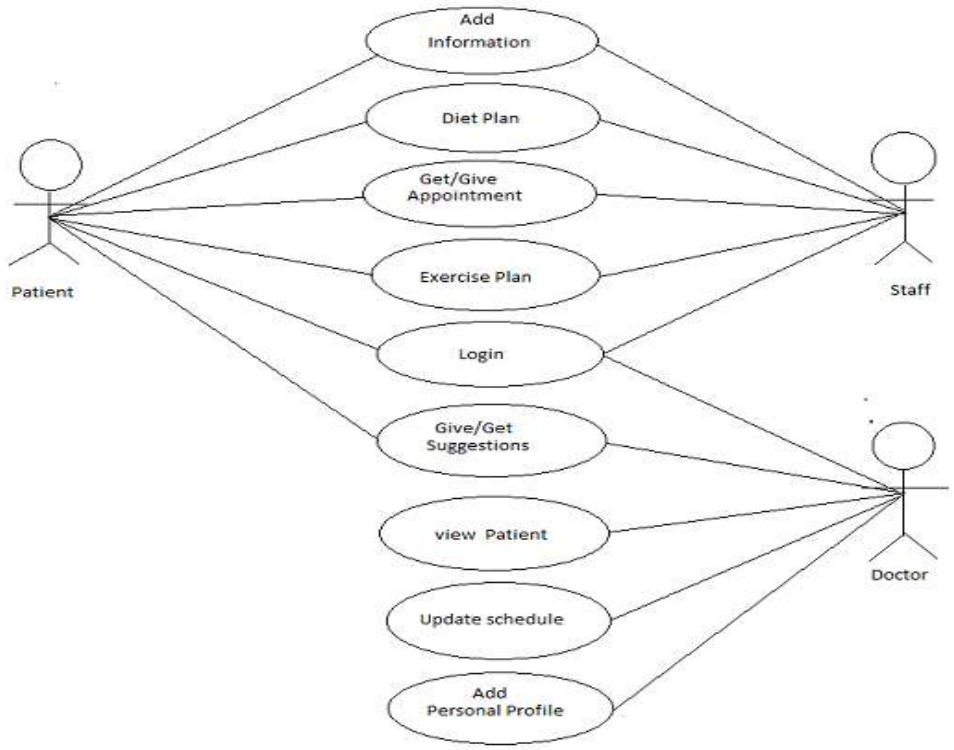


Fig. 3: Users interactions with system

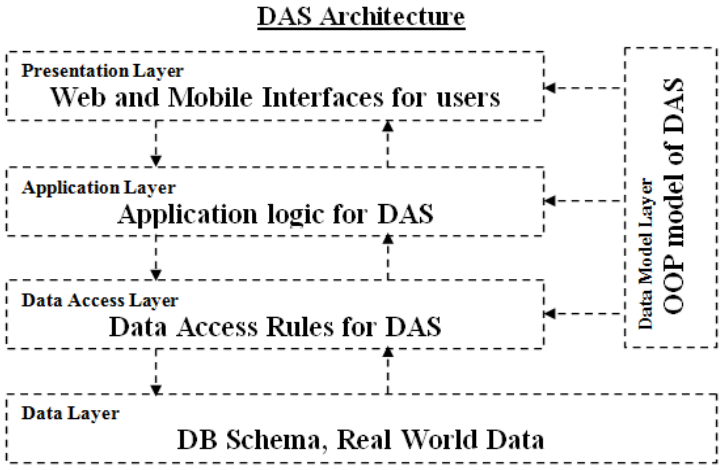


Fig. 4: System architecture

possible, so that the web server work like bridge between the end user and the DB server.

The system is being used by the patient, doctor or staff using PC, Laptop, or Smartphone. User (Patient/Doctor) can login to the system is provided access to those features that are assigned to user role.

DAS is logically divided into five layers as shown in Fig. 4.

Presentation layer encapsulates front-end of the system. It contains the interfaces for the user that facilitates in easy interaction with system both offline and online. The presentation layer facilitates the users to perform all data management operations including update, delete, modify and retrieve information. In addition to this these interactive interfaces enables the user to get more versatile results.

Application layer exists on the web server and facilitates in communication between presentation layer and other layers of the system. This layer contains all the business logic and rules that are the basis of effective operations in the system. This logic defines that how different data sets are generated and how to access these data sets. In addition to this application layer encapsulates business rules that how different operations are performed in the system and which user can access a particular operation in which way.

Data access layer is responsible for how to get communicated between web server and DB server. The interaction between web server and DB server basically includes the data access from the database. The DAL helps in establishing connection with DB as well as it contains all queries and stored procedure calls to interact with backend DB.

Data model layer contains information about all entities in the system and decides that which data must be accessed and when from the Data base. Moreover, it defines the whole Object Oriented model of the system.

Data Layer encapsulates the DB server. Data Layer contains all the data and provides DB Management services and DB schema that maps the real world entities. SQL server is used to provide the data services.

SYSTEM UTILITIES

Mobility: An important module of the system is Mobile Application. The patient or doctor can use the system anywhere anytime on their mobile phones. DAS's availability on smart phones makes it an attractive choice for user and its first complete DMS that not only provides Diabetes management features on mobile but enables the users to interact and socialize to share their experiences and lifestyle management activities.

Web component: Web application make patient communicate to the doctor. Patient can get suggestions while sitting at their home only by logging in to the system using internet. By using this module doctor can check patients' medical history and daily activities etc. In addition to this, users do not have to install any software except web browser and can get instant feature updates without any re-installation.

Authentication/authorization: Every time when patient or doctor will use the system they have to enter their password and id. Login module makes sure that the authorized person is entering the system. Invalid user is not permitted to enter the system. A susvey was made on n = 276 persons that if they want to share their medical data with others or not.

Figure 5 shows the results of the survey graphically which represents that 56% people were disagree to share their information and only 7% were agree. It shows that most of the people don't like to share their medical information with others. So DAS is providing the login feature to protect the system from unauthorized access.

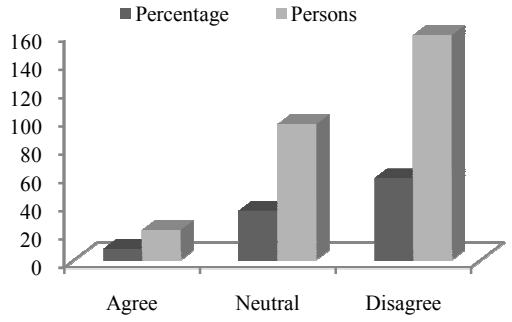


Fig. 5: Users willing to shares their medical data

Reduced costs: DAS is free of cost itself; but there is a little operating cost associated with this. The operational cost incurred on internet connection and first-time setup of devices is very less than the actual cost of the system that a user does not feel any financial burden while using DAS.

SYSTEM FEATURES

Diabetes is a chronic disease that requires the accurate and regular management for the treatment. Smith *et al*. (2009) conducted a study on different diseases and discovered their associated health features that are necessary for the treatment. According to this study the main features that are needed to assist the diabetes management are access to care, blood pressure, blood glucose and diet. Some other important features include education about disease, medication, physical activity, weight and substance abuse.

After thoroughly reviewing the literature and available Diabetes Management Systems, some key features were identified that could be the essential requirements for any state-of-the-art DMS. A detailed questionnaire was prepared under the supervision of a medical specialist and feedback from 12 doctors and 35 patients was taken to engineer the requirements of the proposed system. The results of the questionnaire were compiled and all the features that are required by more than 30% of the respondents are incorporated into the system. These features are related to user management, doctor's schedule management, patient's appointment management, visit management, history management, socializing and disease management. Some other features relating mobility and easy to access are also included in the system.

The key User Management features are registration, authentication and profile management. A user registers by selecting a particular role as a Doctor, Patient, or Staff and enters his/her basic login information and gets registered after a proper authentication from DAS. Only patients are allowed directly to use the system but doctor and staff first have to be verified by the DAS authorities and then they are allowed to use the system. By completing the registration process, every user can manage his personal profile that contains the basic information of the user, In addition to this; doctor can manage his/her educational profile while a patient can manage his medical profile in detail.

Schedule management features includes (re) scheduling the schedule by doctor. A doctor can prepare his/her monthly schedule by selecting a particular month and describing his/her availability on different time slots. All the users can view the schedule of particular doctor(s).

Appointment Management features includes taking appointments, modifying appointments and cancelling a particular appointment. A patient or staff has the access to appointment management features in DAS.

Visit Management features enable a doctor and patient to not only interact face to face but also they can collaborate remotely using some video/audio calling software or by phone. This facilitates the patient to get advice remotely. During visit session, a doctor enters a patient's reporting condition that is the condition of patient at the start of the visit and records his BP, Weight, Temperature and Pulse. In addition to this, a doctor may advise some diagnostic tests, medicines, foods and exercises before concluding the visit.

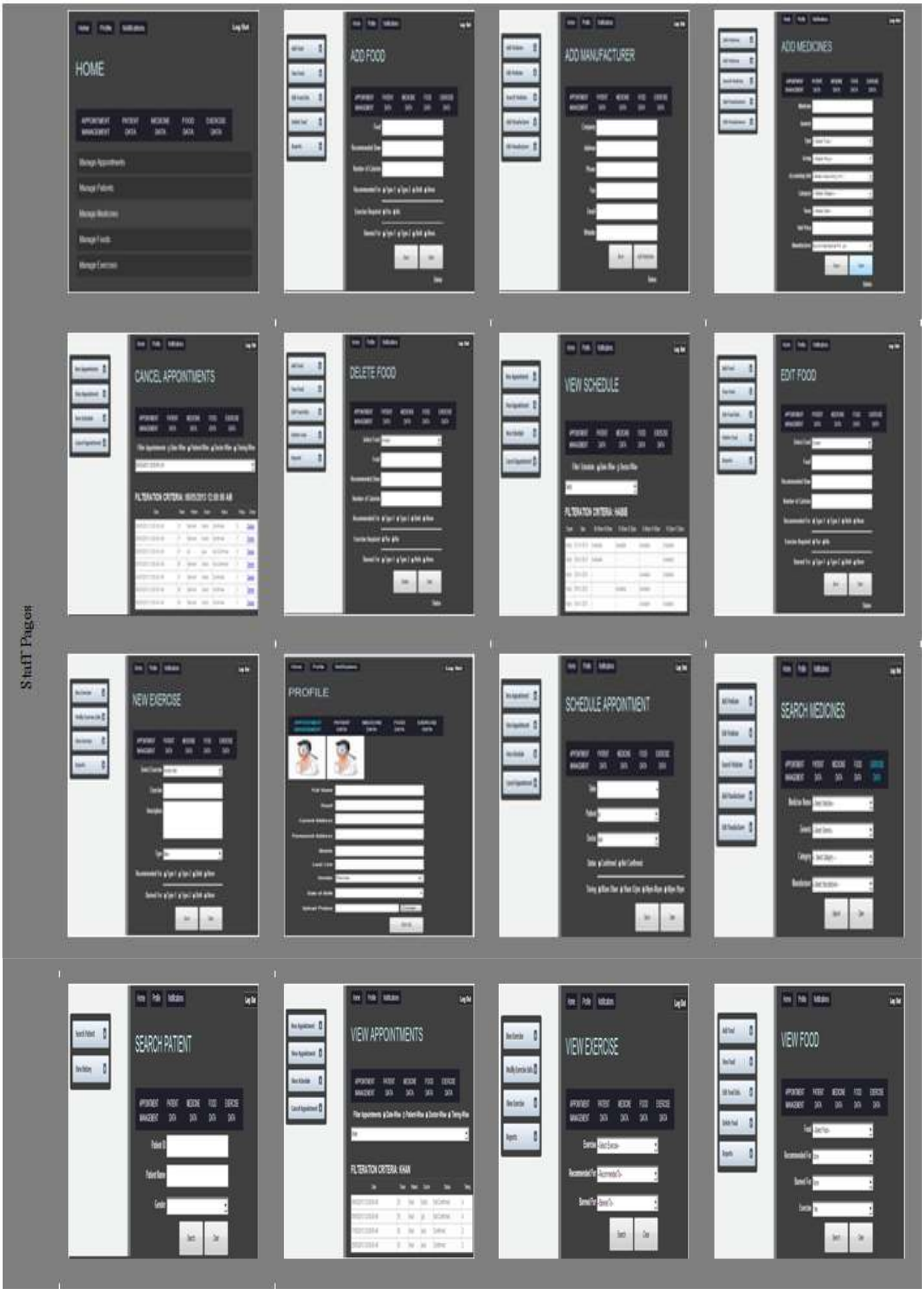
History Management features includes the history of visits and patients' daily lifestyle activities. Visit history includes the information of all previous visits. A user, doctor or patient, can refine the history on the basis of different criteria and can also view the history of some particular visit element like dates, medication, tests, foods etc. Patient's lifestyle history features are more interesting in the sense that it gives an insight into a patient's actual diabetic lifestyle. In this history, a user, patient or doctor can view the daily intakes of foods and medications and can read the tests monitoring and physical activities. A doctor on the basis of this history can make an effective decision while advising a patient. Lifestyle history can also be refined to different criterion and parameters.

Socializing is another key feature of DAS. A public blog is prepared for this purpose to collaborate the information about personal diabetic lifestyles. This is a public blog and any registered/unregistered user can use this blog to publish their articles and give feedback on those articles. In addition to this, any user can share videos and audios. Every post on the blog is subject to approval of the webmaster of the DAS.

When it comes to diabetic lifestyle management, there comes a need for a proper feedback system that records a patient's daily activities that effect insulin level of the patient. To facilitate the user in managing his/her diabetic lifestyle; Tests, Exercises, Foods and medications' management features are included into DAS. By using DAS, a user can easily record his daily activities and view previous information of his/her.

The screenshots and details of all these features can be witnessed in Fig. 6.


Static Web Pages
diassist
Doctor Pages
VISUAL PROFILE
DISEASE WISE PATIENTS
EDUCATION
DISEASE WISE PATIENTS
START A NEW VISIT
PERSONAL PROFILE
SURGERIES
TODAYS PATIENTS


Staff Pages
HOME
ADD FOOD
ADD MANUFACTURER
ADD MEDICINES
CANCEL APPOINTMENTS
DELETE FOOD
VIEW SCHEDULE
EDIT FOOD
NEW EXERCISE
PROFILE
SCHEDULE APPOINTMENT
SEARCH MEDICINES
SEARCH PATIENT
VIEW APPOINTMENTS
VIEW EXERCISE
VIEW FOOD

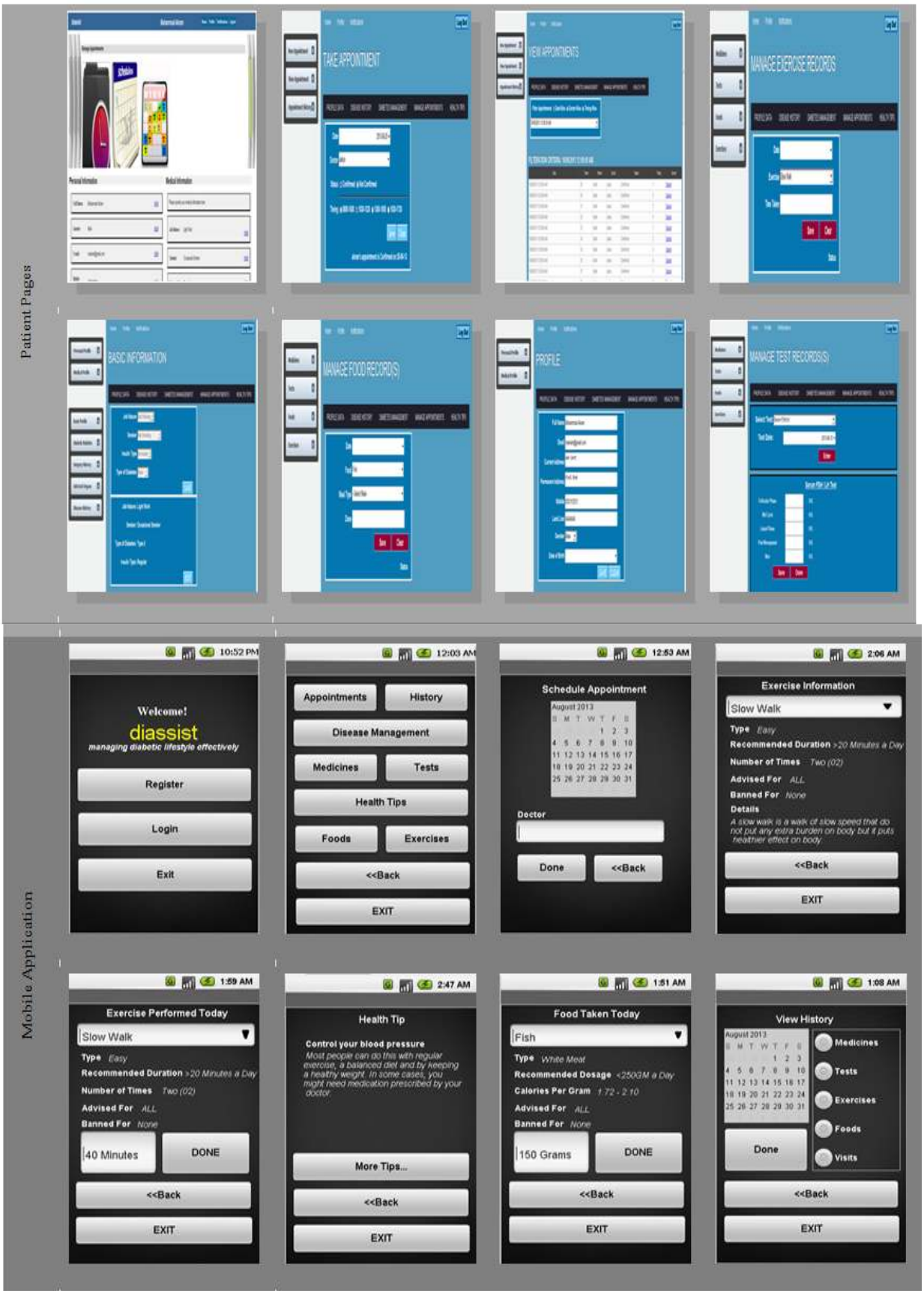

Patient Pages
TAKE APPOINTMENT
VIEW APPOINTMENTS
MANAGE EXERCISE RECORDS
BASIC INFORMATION
MANAGE FOOD RECORD(S)
PROFILE
MANAGE TEST RECORD(S)
Mobile Application
10:52 PM
Welcome!
diassist
managing diabetic lifestyle effectively
Register
Login
Exit
12:03 AM
Appointments
History
Disease Management
Medicines
Tests
Health Tips
Foods
Exercises
<<Back
EXIT
12:53 AM
Schedule Appointment
August 2013
Doctor
Done
<<Back
2:06 AM
Exercise Information
Slow Walk
Type Easy
Recommended Duration >20 Minutes a Day
Number of Times Two (02)
Advised For ALL
Banned For None
Details
A slow walk is a walk of slow speed that do not put any extra burden on body but it puts healthier effect on body.
<<Back
EXIT
1:59 AM
Exercise Performed Today
Slow Walk
Type Easy
Recommended Duration >20 Minutes a Day
Number of Times Two (02)
Advised For ALL
Banned For None
40 Minutes
DONE
<<Back
EXIT
2:47 AM
Health Tip
Control your blood pressure
Most people can do this with regular exercise, a balanced diet and by keeping a healthy weight. In some cases, you might need medication prescribed by your doctor.
More Tips...
<<Back
EXIT
1:51 AM
Food Taken Today
Fish
Type White Meat
Recommended Dosage <250GM a Day
Calories Per Gram 1.72 - 2.10
Advised For ALL
Banned For None
150 Grams
DONE
<<Back
EXIT
1:08 AM
View History
August 2013
Medicines
Tests
Exercises
Foods
Visits
Done
<<Back
EXIT

Fig. 6: Some of the screen shots of actual system are being presented so that a user can have a look inside the system

EVALUATION RESULTS

DAS is deployed on a private web server with limited access to only particular users so that it could be evaluated and updated accordingly before final release of the system. The system was evaluated by 72 doctors, 183 patients and 7 staff members. In very first iteration, users had rated the DAS 7/10. In the 2nd and 3rd evaluations, conducted in 2nd and 3rd months of its initial deployment, DAS had ratings of 7.75/10 and 8.30/10, respectively. After, the third evaluation, it is decided to launch it for public use and the system will be publically available in January 2014.

Survey summary: For the evaluation of the system a survey was made on the basis of a questionnaire containing ten questions about the system. This survey was made on n = 276 which includes 21 staff members 183 patients and 72 doctors. SUS results are shown in Table 2. Aggregate percentage of the results is 67.1% which indicates that the system is working well and useful.

Figure 7 graphically represents the survey result, whichwasmadeon183 patients. This shows that the need

Table 2: System utility survey results

No.	Question	Agree (%)	Neutral (%)	Disagree (%)
1	Internet service is useful	90	10	0
2	Mobile apps required	90	10	0
3	Difficulty in visiting doctor	64	21	15
4	The system is simple	62	11	27
5	Manage appointments	50	7	43
6	Inconsistency in system	10	34	56
7	Will use the system in future	64	25	11
8	Technical skills required	28	0	72
9	All functions are well integrated	50	32	18
10	Additional learning required	2	0	98

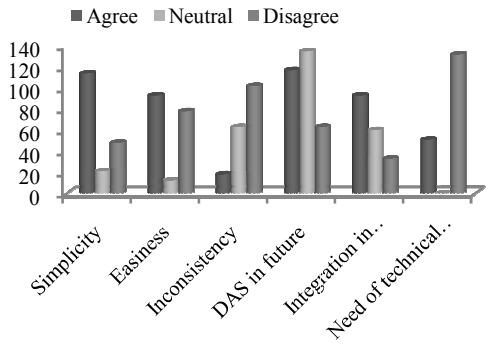


Fig. 7: System utility survey result of 183 patients

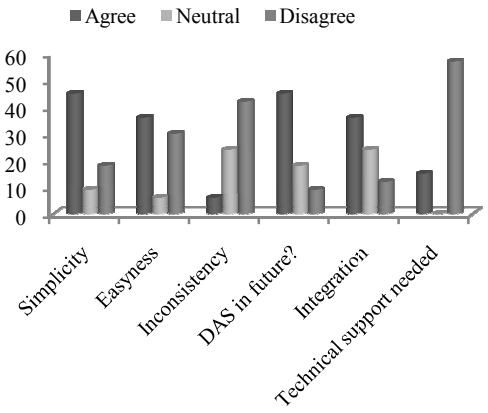


Fig. 8: System utility survey result of 72 doctors

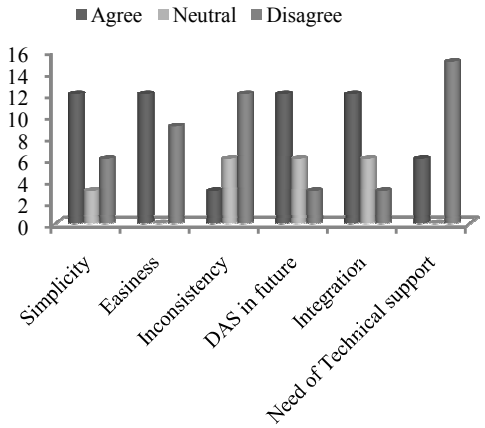


Fig. 9: System utility survey result of 21 staff members

of technical support has high percentage in patients. This is because all patients may not be educated.

Figure 8 and 9 shows graphical presentation of the survey results which was made on 21 staff members and 72 doctors, respectively. Results indicates that the system is enough useful for both the doctors and staff members. According to the results, system is easy and simple and about 64% of the people are agree to use DAS in future.

CONCLUSION

We proposed a system that provides all the basic and necessary features for the management of diabetes. The system provides the mobility feature that make patient able to use system anywhere around the world using Internet. The system allows the regular communication between the doctor and patient that develop the sense of security in patient. System provides the management of Diet, Exercise, Tests and medicine. The system is good enough in terms of patient's feedback.

DAS is developed by keeping user's availability and ease of access in mind as it can be used by any device connected with Internet including smart phones and PCs. DAS can be extended to non-smart phone mobile devices so that minimum features can be accessed even only using SMS on mobile phones. In addition to this, at present, users manually enters most of the data into the system, This overhead can be minimized by incorporating those features that allow the users to automatically enter his/her data. Some health monitoring devices for BP, Temperature and Sugar level can be easily added for automatic input into DAS. Furthermore, a video conferencing and messaging application can be added so that users can collaborate directly without using any third party software. Furthermore, a location detection application can be added that locates a particular patient and suggest him/her the nearest medical centers and doctors.

REFERENCES

Abrahams, M.C., 2010. E-health diabetes management system. Honours Project Report Department of Computer Science, University of Cape Town, South Africa.

Brian, S.S., 2011. Mobile Diabetes Management System. CSC4000W Honor Project Report.

Fuchao, Z., 2011. Mobile personal health care system for patients with diabetes. B.A. Thesis, Iowa State University, Paper 10332.

Lutes, K.D., K. Chang and I.M. Baggili, 2006. Diabetic e-Management System (DEMS). Proceeding of 3rd International Conference on Information Technology: New Generations (ITNG 2006), pp: 619-624.

Osama, S., 2012. A mobile phone SMS based system for diabetes self management. Int. Arab J. e-Technol., 2(3): 161-166.

Park, K.S., N.J. Kim, J.H. Hong, M.S. Park, E.J. Cha and T.S. Lee, 2005. PDA based point-of-care personal diabetes management system. Proceeding of IEEE-EMBS 27th Annual International Conference of the Engineering in Medicine and Biology Society, pp: 3749-3752.

Rudi, R. and B.G. Celler, 2006. Design and implementation of expert-telemedicine system for diabetes management at home. Proceeding of International Conference on Biomedical and Pharmaceutical Engineering (ICBPE, 2006), pp: 595-599.

Smith, P.C., E. Mossialos, I. Papanicolas and S. Letherman, 2009. Performance Measurement for Health System Improvement: Experiences, Challenges and Prospects. Health Economics, Policy and Management. Cambridge University Press, Cambridge, UK, ISBN: 9780521116763.

Vigersky, R.A., E. Hanson, E. McDonpugh and Robert S. Galen, 2003. A wireless diabetes management and communication. Diabetes Technol. Ther., 5(4): 695-702.