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Application of Communication Agents for Virtual Personal Assistant E-Health Service

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***Abstract*—Information and Communication Technology (ICT) is enhancing health care delivery and quality of service. The application of communication agents for virtual personal assistant e-health service will enable agent to agent communication as well as patient and medical specialist interaction in order to improve health care service delivery. The platform will enhance regular interactions between diabetic patients and medical specialist and reduce clinic visits, cost, save time and increase productivity. The design of the application and user interface was iterative and a user centered approach was applied. During the study, interviews and surveys were conducted to elicit data from potential users for system development. The e-health service was tested and evaluated by participants from the medical facility and the community. During the testing and evaluation processes, qualitative and quantitative data were collected and analyzed. The results show that the interactive agents communicated with each other to achieve the agents' different goals such as updating themselves with new information. Also the agents could correctly add and retrieve data from the electronic record and diabetes diary and sent it to the recipients. The user evaluation results also indicates that 98% of the users completed different tasks by interact with each other (patient to medical specialists and medical specialist to patients) through the user interface. The participants were also positive (Mean score = 3.63 and Standard Deviation = 0.90) that the application will improve regular interactions between patients and medical specialists. The users were pleased with the performance of the system.**

Keywords—Communication Agent; Virtual Personal Assistant; e-Health; Multi-Agent system; Information and Communication Technology

I. Introduction

Information and Communication Technology (ICT) is gradually changing the way healthcare services are delivered to the patients. The goal is to use ICT to provide health services even in remote locations where medical personnel are scarce. Application of agent oriented technology in the development of software is receiving tremendous attention. Agent-based systems for ICT services can enhance the provision of quality service including health care delivery. Agent-Oriented Programming (AOP) is a relatively new software paradigm that brings concepts from the theories of artificial intelligence into the mainstream realm of distributed systems. AOP essentially models an application as a collection of components called agents that are characterized by, among other things, autonomy, proactivity and an ability to communicate. Being autonomous means the agents can independently carry out complex, and most often long-term tasks. Being proactive they can take the initiative to perform a given task even without an explicit stimulus from a user. As communicative agents, they can interact with other entities to assist with achieving their own and others' goals.

Agent technology has been the subject of extensive discussion and investigation within the scientific community for several years, but it is perhaps only recently that it has seen any significant degree of exploitation in commercial applications. Multi-agent systems have been applied in different application areas, such as small systems for personal assistance, open and complex mission-critical systems in several industries [1]. Application of agent technology in e-health application enhances communication among the interacting entities.

E-Health involves the use of Information and Communication Technology (ICT) in the health sector to enhance the healthcare. In particular, the use of Multi Agent System (MAS) technology, an aspect of ICT, can further contribute to the improvement of healthcare. Exceptional integration of this technology requires a Cognitive Engineering (CE) approach; implying that the design and implementation of the architecture is done incrementally and using multiple distributed agents. This is facilitated by easy data entry, management and verification by all the actors involved. Consequently, this study applied an agent architecture consisting of a Virtual Personal Assistant that supervises patients' self-care, with chronic illness. The design also includes a user interface that enable the patients interact with the care givers. In this study, e-Health is the application of ICT in diabetic patients care; rule-based reasoning is combined with Multi Agent Systems (MAS) technology using mathematical models of blood glucose regulation for the identification of problems and treatment generation. Subsequently, treatment can be prescribed, including insulin therapy, diet and physical exercise.

E-Health solutions using Multi Agent System (MAS) technology can provide functionalities for personalized assistance with multiple distributed actors, e.g., patients, physicians, and other medical specialists [2] [3] [4]. These solutions include improving relationships between clients and caregivers, detecting adverse trends in health proactively, stimulating a patient's motivation and bringing about behavioural changes. The latter is required for effective self-care, patient's quality of life, information sharing with the involved medical specialists, and productive and low-cost self-care.

The study was carried out to develop and deploy an e-Health service for the medical center in a tertiary institution (Akanu Ibiam Federal Polytechnic). The medical center of the institution provides healthcare services to the staff and students and the nearby communities as part of its community development service. Access to Internet services in the medical center is through the use of mobile devices such as smart mobile phones, laptops and tablets. The communities closed to the institution are low income communities, and the medical center have to deal with this type of financial situation and still render health services to the people. Also, apart from mobile phone services, the use of Internet services is very low among the people of the communities [5]. The application provides a platform for the medical personnel in the clinic to interact with diabetic out patients within the communities close to the medical facility. These communities contain the aged and young people as well as people who may have worked in the institution and retired. The community people form part of the target of this study.

II. Literature Review

A. Multi Agent Systems (MAS)

MASs are considered as a network of loosely coupled problem solvers that communicate to solve problems that surpass an individual capabilities or the understanding of individual problem solver [6]. These problem solvers, often called *agents*, are autonomous and can be heterogeneous in nature. The characteristics of MASs [7] are that (1) each agent has incomplete knowledge or capabilities for solving the problem and, thus, has a limited viewpoint; (2) there is no global control of the system; (3) data are decentralized; and (4) computation is asynchronous.

The motivations for the increasing interest in MAS research include the ability of MASs to do the following: the first is to solve problems that are too large for a centralized agent to solve because of resource limitations or the sheer risk of having one centralized system that could be a performance bottleneck or could fail at critical times. The second is to allow for the interconnection and interoperation of multiple existing legacy systems. To keep pace with changing business needs, legacy systems must periodically be updated. Completely rewriting such software tends to be prohibitively expensive and is often simply impossible. Therefore, in the short to medium term, the only way that such legacy systems can remain useful is to incorporate them into a wider cooperating agent community in which they can be exploited by other pieces of software. The third is to provide solutions to problems that can naturally be regarded as a society of autonomous interacting components-agents. For example, in meeting scheduling, a scheduling agent that manages the calendar of its user can be regarded as autonomous and interacting with other similar agents that manage calendars of different users [8]. Such agents also can be customized to reflect the preferences and constraints of their users. Other examples include air-traffic control [9] [10] and multi agent bargaining for buying and selling goods on the internet. The fourth is to provide solutions that efficiently use information sources that are spatially distributed. Examples of such domains include sensor networks [11], seismic monitoring [12], and information gathering from the Internet [13].

The fifth is to provide solutions in situations where expertise is distributed. Examples of such problems include concurrent engineering [14], health care, and manufacturing. The sixth is to enhance performance along the dimensions of (1) *computational efficiency* because concurrency of computation is exploited (as long as communication is kept minimal, for example, by transmitting high level information and results rather than low level data); (2) *reliability*, that is, graceful recovery of component failures, because agents with redundant capabilities or appropriate interagent coordination are found dynamically (for example, taking up responsibilities of agents that fail); (3) *extensibility* because the number and the capabilities of agents working on a problem can be altered; (4) *robustness*, the system's ability to tolerate uncertainty, because suitable information is exchanged among agents; (5) *maintainability* because a system composed of multiple components-agents is easier to maintain because of its modularity; (6) *responsiveness* because modularity can handle anomalies locally, not propagate them to the whole system; (7) *flexibility* because agents with different abilities can adaptively organize to solve the current problem; and (8) *reuse* because functionally specific agents can be reused in different agent teams to solve different problems.

B. Multi Agent System Issues/ Challenges and Solutions

Although MASs provide many potential advantages, they also present many difficult challenges. [15] identified several challenges which include: Firstly, the difficulty of formulating, describing, decomposing, and allocating problems and synthesize results among a group of intelligent agents. Secondly, communication and interactions among agents is also a big challenge. Identifying the right communication languages and protocols is difficult. The possibility for heterogeneous agents to interoperate is also a challenge. Thirdly, enabling agents to act coherently in decision making or taking action, accommodating the nonlocal effects of local decisions and avoiding harmful interactions. Fourthly, the challenge of enabling individual agents to represent and reason about the actions, plans, and knowledge of other agents to coordinate with them. Fifthly, the challenge of recognizing and reconciling disparate viewpoints and conflicting intentions among a collection of agents trying to coordinate their actions. Sixthly, the challenge of engineering and constraining practically Distributed Artificial Agent (DAI) systems.

Solutions to these problems are intertwined and these include application of the right modeling scheme for agents, appropriate problem and task decomposition and coherently organizing them for agents. Coherence is a global (or regional) property of the MAS that could be measured by the efficiency, quality, and consistency of a global solution (system behaviour) as well as the ability of the system to degrade gracefully in the presence of local failures. Methods for increasing coherence and the issues of single-agent structuring in MAS include 1) Sophisticated individual agent reasoning to increase MAS coherence because each individual agent can reason about nonlocal effects of local actions, form expectations of the behaviour of others, or explain and possibly repair conflicts and harmful interactions. 2) An organized framework for agent interactions through the definition of roles, behavior expectations, and authority relations. 3) Task allocation to assign responsibility and problem-solving resources to an agent. Also, minimizing task interdependencies can improve problem-solving efficiency by decreasing communication overhead among the problem-solving agents. It also improves the chances for solution consistency by minimizing potential conflicts. 4) Multi agent planning can improve coherence by planning their actions. 5) Recognizing and resolving conflict disparities and inconsistencies in agents' goals, plans, knowledge, beliefs, and results can be recognized and resolved through negotiation. 6) Modeling other agents with knowledge about other agents or the ability to model and reason about others in order to increase the accuracy and efficiency of their problem solving. This will also increase agent's flexibility, provide information about other agent's knowledge, beliefs, and goals that are useful in planning and communicating or allowing coordination without communication.

C. Virtual Personal Assistant Activities

The Virtual Personal Assistants enable the human actors to interact with the different agents in the environment. The interactions can take place through activities such as data entry, policies formulation and making of recommendations. The care giver (medical personnel) will enter data about patient information such as demographic data, medical history, and clinical diabetes information. The patient on the other side keeps track of self-care tasks in a personal electronic diabetes diary. These include current mood, exercises performed, meals consumed, medication taken, and blood glucose measurement results. The medical personnel and the patient enter the data through the Virtual Personal Assistant (VPA) into the database. The Virtual Personal Assistant usually provides policies or suggestions either in the short term or long term. The policies or suggestions are dependent on the data or information available in the patient's record. The VPA is very essential in monitoring the patient health status such as for diabetes care. It will usually formulate its policies based on the results obtained from the patient's electronic records.

A Virtual Personal Assistant (VPA) act as an intermediary between the users and the active agents in the application [4] [16]. Data is shared between the user and the agents as the users interact with the VPA. Agent-based technology provides enabling environment for the conceptualization and development of complex systems. Agent-based systems are intelligent and operate in open and distributed environments. The Internet is an enabling environment for agent-based applications.

D. Agent Communication and Database

Different agents run simultaneously on the patient and medical specialist's computers and communicate with each other for optimal functionality. In this study, two agents have been implemented using the JADE platform, i.e., the *PatientAgent* at the patient's side, and the *MedicalSpecialistAgent* at the medical specialist's side. The agent communication takes place by sending messages from both sides. In order to recognize the different kind of messages, the behavior of the agents changes according to the prefix of the message. If the message starts with "*start*", the chat becomes active; if it starts with "*chat*", the chat window will show the message sent by the medical specialist. The third type of prefix is "*response*" followed by the name of the measurement, i.e. blood pressure or glucose level. Also, the *PatientAgent* checks how the new measurement influence the status of the patient.

E. Application of MAS in E-Health

Information and Communication Technology (ICT) application in the health sector is radically changing today's health care [17]. With the increase in network connectivity speed and the decreasing health care costs, e-Health has the capacity to considerably increase the availability of self-care options by supporting patients' decisions-making and supervised autonomy [18]. Hence, application of communication agents for virtual personal assistant will help to improve patient's health care, not only in the treatment of diabetes but also in treating other chronic diseases when implemented. MAS architecture allows for expansion to accommodate more distributed actors, both human, machine, and tools such as medical devices and data sources e.g., electronic patient records. Based on the MAS architecture, the agents communicate with each other and receive information through sensors placed in the smart environment. The multiple agents do also acquire information through their behavior or their communication.

Agent-based systems technology has generated lots of excitement in recent years because of its promise as a new paradigm for conceptualizing, designing, and implementing software systems [7]. This promise is particularly attractive for creating software that operates in distributed and open environments such as the Internet. Most agent-based systems consist of a single agent. However, as the technology matures and addresses increasingly complex applications, the need for systems that consist of multiple agents that communicate in a peer-to peer fashion has become apparent.

Real problems involve distributed, and dynamically changing open system. The characteristics of such a system are that its components are not known in advance, and they can change over time. The system can also be made of highly heterogeneous agents that are applied using different software tools and techniques at different times by different individuals. An example of a highly open software environment is the Internet. The Internet is a collection of large, distributed information resource and consisting of network of nodes from different organizations and individuals. In an open environment, information sources, communication links, and agents could appear and disappear unexpectedly. Currently, information retrieval and filtering are the main tasks performed by agents on the Internet. In the future, agents will be able to undertake information gathering and sophisticated reasoning to support user problem-solving tasks. This requires that agents have the capabilities to interoperate and coordinate during peer-to-peer interactions with each other.

Nikos [19] described a Personal Assistant Agent (PAA) as one that interacts with the user environment and application in several ways in order to assist the user to make decisions, perform tasks, monitor events and tackle all the complexity tasks. PAAs intelligence enables them to adapt and customize users' needs under different circumstances. Agent and PAA can be enabled to gather information for users, analyze and produce results, decide an action or sequence of actions and carry out the action if they are based on multi-agent system technology.

PAA has the capabilities to perform personalized services at anytime and anywhere. The PAA intelligence and adaptive capabilities helps it in making reliable decisions and plans. The PAA decision becomes reference points to the users who utilize those decisions as inputs to gather more detailed and accurate information for each plan and activities.

III. Methodology

The study was divided into three tasks that include requirement gathering, system design and prototyping, and system testing and evaluation. A user-centered approach was adopted for the study and different research methods were used to collected data for system design and evaluation. Secondary sources were also used to source for data. The secondary sources include the Internet and library materials. A survey was also carried out to determine level of usage and user's view of the e-health system after its deployment.

A. System Study and Requirements Gathering

Interviews were conducted with the medical doctors, nurses and lab scientists/technologists and patients. These were staff of the medical center in Akanu Ibiam Federal Polytechnic. The medical facility provides medical services to the staff and students of the Polytechnic and the host community. The data required at this stage was what was needed for the treatment and management of diabetes disease. Other data also gathered were relevant for the development of the application and user interface elements such as elements needed for customization of the interface to suit the various medical personnel activities. These include icons, menu items, and other interaction elements. A survey on the availability and usage of ICT infrastructures within the medical facility and surrounding environment was also conducted. This was very relevant because it will influence the acceptance and usage of the application. During the interviews, 20 staff were interviewed in the medical center. Interview with the staff was not a smooth process, because some of the staff could not create adequate time to be interviewed. In some cases, appointments with the staff were made yet they were never available for the interview. During the interviews, six (6) medical laboratory scientists/technologists, nine (9) nurses, and five (5) doctors, were interviewed. The interview was conducted using a structured questionnaire as a guide. Field note was used to write down the responses from the participants. The qualitative and quantitative data collected were analyzed and used to design the application. The study also involved interactions with people living in the communities to find out the level of ICT awareness and usage, the primary source of their medical needs and their relationship with the medical facility in the institution.

B. System Prototype Development

The system development process was iterative. It passed through series of test and modification processes. The data gathered during the requirement process was used to develop the system. The System Architectural model (Fig. 1) shows the flow of interactions between the patients, medical specialist and the VPAs. At first, the Patient checks glucose level using glucometer and enters the reading into the system through the patient user interface. When both Virtual Personal Assistants are online, they should correctly add and retrieve data to and from the

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database, containing the electronic patient record (EPR) and the electronic diabetes dairy. When the patient's VPA is offline, it could still give comment on the diary entry and subsequently add the new data to the database. When the patient's VPA becomes online again, the medical specialist's VPA could synchronize the new data. The medical specialist will also interact with the patient through the VPAs. The VPA use the readings, analyze the value and give the patient the required advice. The application was hosted on the Internet and was made active to enable users interact with it during the testing and evaluation processes.

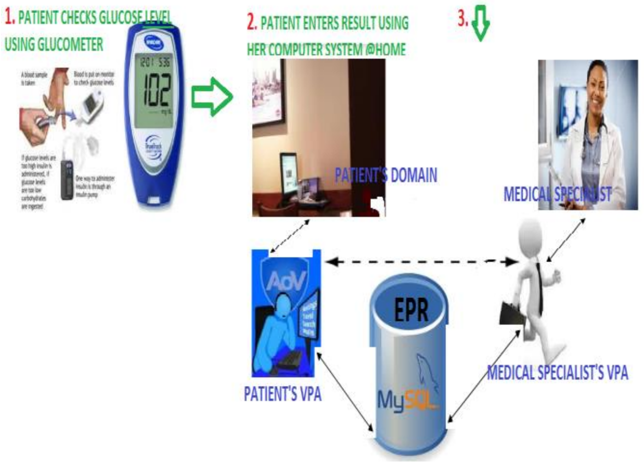

Fig. 1. *The System Architectural Model*

C. System Evaluation

The user evaluation of the application was conducted with participants in the medical center. Laptops with modem were used to connect to the Internet in order to have access to the application. A cybercafé in the community as well as Internet connected laptop were also used to enable participants in the community to participate. The participants include the medical personnel and patients that we were able to contact through the clinic. The participants were given time to carry out a brief study of the system. Single user evaluation processes were conducted with each participant at different times. The participants were given tasks to perform. After the tasks execution, the participants were asked to give their observations and opinion about their experiences with the application. Participants were asked to create their login details (only for patient actors), while the medical specialist actors were given a default login. The next task for the patients involved logging in and using the user interface to enter a glucometer reading and also checking for medical reports and recommendations. The medical specialists were asked to give prescription response to the patient status based on the reading entered by the patient. The participants were observed and notes were taken while they performed the tasks. Post-test interviews and questionnaires were used to collect evaluation data for statistical analysis. Post deployment assessment of the application was also conducted to find out if the system have any positive influence on the users.

IV. Results and Discussion

A Communication Agents System and user interface was developed initially for the management of diabetes. The user interface enables the patient and medical specialist to interact easily without necessarily visiting the clinic. The application will enable the users to have regular interactions with each other, reduce the cost of going to the clinic, as well as save patients and medical personnel time. The application and user interface were evaluated by the potential users (patients and medical personnel). The user evaluation of the system shows that the participants were pleased with the application and they carried out interaction with ease and encountered little or no difficulty. The users who used the e-health application agreed that it will have positive impact on their lives in the long time and they will be able to have regular interaction with their care givers.

A. Evaluation of Agent Characteristics

The characteristics of agents that were evaluated include autonomy, proactivity and the ability to communicate. These characteristics were tested in the system to find out the performance of the agents. As autonomous agents, the agent perform tasks such as computing the blood sugar level based on the glucometer value and giving recommendations to the users. The agents were required to be proactive to events in the system. Being proactive the agents could initiate the performance of any given task even without an explicit stimulus from a user. This requirement was obvious as the agents needed no reminder to give judgment immediately they computed the individual glucose level. As interactive agents, they could communicate with other entities to assist with achieving their own and others' goals. Both the patient's VPA and the medical specialist VPA interacted with each other, thus achieving the goal of updating each other with new information whenever it was necessary.

When both Virtual Personal Assistants agents were online, they could correctly add and retrieve data to and from the database, containing the electronic patient record (EPR) and the electronic diabetes dairy. In the case of a critical health situation or when the patient sent a message to the medical specialist, the two VPAs could communicate with each other directly. In practice, the patient logged self-care tasks in the electronic diary and based on the data, the patient's VPA made inferences about the patient's health status and gave feedback. The new data, based on the interaction between the patient and its VPA, was then sent to the database and retrievable by the medical specialist's VPA. The patient's VPA reacted accurately and quickly to the newly added data of the patient electronic diary independent of the type of task or the health situation of the patient. The data was correctly added to the database and retrieved by the medical specialist's VPA. Also, the communication between the two VPAs was instantaneous.

B. Internet Availability and Usage

Internet services are available in the medical center and the community through the mobile telecommunication network services. The institution also has its ICT center where Internet services are available for users; although the staff of the institution and medical personnel found it difficult to leave their offices to the ICT center for Internet services. Internet services through the mobile telecommunication networks are preferable for those that use smart phones and Internet enabled mobile devices. The use of laptops and modem to access Internet in the medical center has become popular for some time now. Although the cost of getting Internet services through these methods is paid by the user instead of the institution. The wireless network hotspots within the institution premise is not vastly used due to low signal quality in most part of the environment. The staff in the medical facility connect to the internet with laptop and USB modem or with other mobile devices (phones and tablets). A survey was carried out to assess how the people within and outside the medical facility use the Internet to access information, e-health service, and e-mail service.

The result from the survey is presented in Fig. 2. The results show that 42% of the respondents use the Internet service to gather information relevant to their field and work area. The users connect to the Internet either through the use of personal devices or through the ICT center or a cyber café. Among the respondents that have access to the Internet for information, 60% use the ICT center that offer this service through a reduced subscription fee, whilst 40% use their mobile devices or laptops and modem for Internet connectivity. 58% of the respondents have no access to Internet service. Their reasons being that they do not have the required facilities like smart phones or laptops, as well as money to pay for subscription at the ICT center. While others say they do not see the need for the Internet. Thirty five percent (35%) of the respondent access health related information from the Internet using their personal mobile devices. A good number of the participants (65%) are not familiar with e-health services, but they indicated interest to start using any available e-health platform.

E-mail is a very common web service provided on the Internet. It is a service that is common among literate populations in urban communities. The proliferation of mobile devices has enabled more people even in rural communities to have access to e-mail service on the Internet. The survey results showed that 49% of the respondents use the e-mail service to communicate with people living outside their community. The majority were respondent working in the medical facility. Out of these e-mail users, 25% send and receive emails most times by using the cyber café/ICT center, while 75% use their personal mobile devices like laptop with modem, tablets or mobile phones for e-mail service. There is no corporate local area network facility in the medical center. The mobile telecommunication network covers the entire institution and the neighboring communities and provide wireless connectivity to the users. The ICT center offer subscription based Internet services to members of the community. Some of the people within the institution do patronize the ICT center for Internet services.

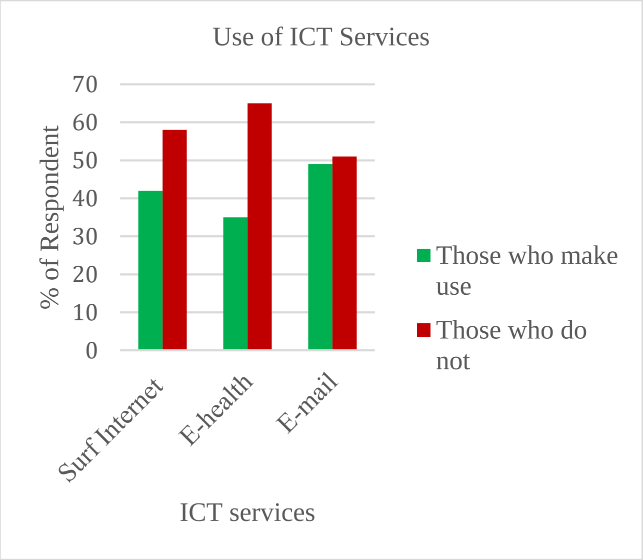

Fig. 2. *Level of usage of ICT Services*

C. The Application Screenshots

The users of the e-health Virtual Personal Assistant application create and store their personal information. This will enable users who are patients to be recognized subsequently whenever they need to communicate with the caregivers/medical specialists. The communication may include sending their daily glucometer reading to know their status, receive prescription/advice from the medical specialists/caregivers and other information. The medical specialists are given default registration details which can be changed at any time. The application generates patient ID automatically during the process of Registration (see Fig. 3).

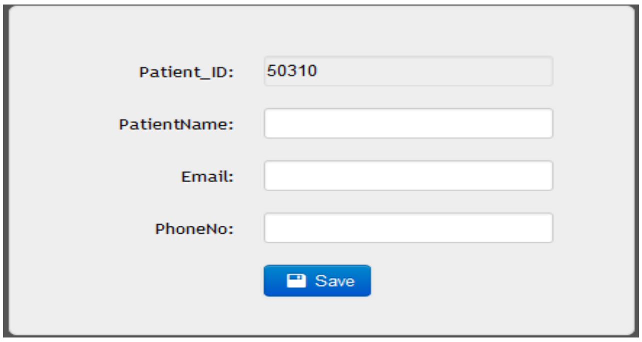

Fig.3. *User Registration Interface*

The user interface in Fig. 4 enables the patients to send the glucometer reading into the system. When a registered user log into the system, Patient name and Patient ID are automatically synchronized and displayed. After entering the reading, the VPA agent calculates the blood sugar level and give recommendations such as directing the patient to the medical specialist/caregiver.

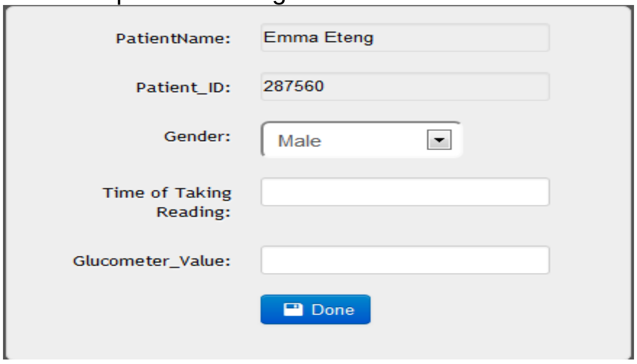

Fig. 4. *Patient User Interface*

The patient's interfaces will enable the user to perform the following tasks:

1. Entering of medical test results and viewing old medical results.
2. A chat service to communicate with the remote medical specialist.
3. A frame to interact with the medical specialist through the Virtual Personal Assistant agent.

The medical specialist also has interfaces used for remote monitoring of the patients. This also includes other tasks such as:

1. View a List of the patients in the medical specialist's folder.
2. Access to Patient Data and Management
3. A chat service to communicate with the patient.

The e-Health application user interfaces are interactive and user friendly. The users, may not require any training for them to be able to use the application.

The patient VPA agent and the medical specialist VPA agent are the communication agents that enable the patient and medical specialist to interact with the System. The patient VPA Agent receives data derived from the patient's electronic patient record, electronic diabetes diary, and domestic medical instruments, e.g., glucometer. Based on this data, the patient's Virtual Personal Assistant interacts with the patient, e.g., about his or her health status and diseases. In addition, it updates the medical specialist's VPA, which in turn informs the medical specialist of the patient situation and supports managing basic medical data. Figure 5 displays an output showing the list of some users that interacted with the system to enter data and receive medical information or advice from the system.

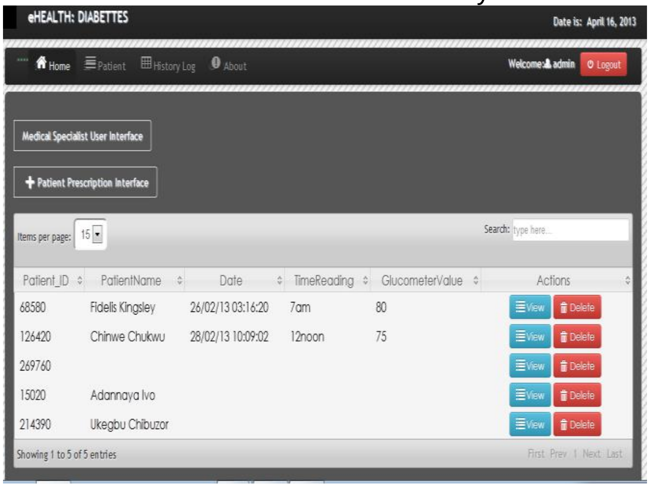

Fig. 5. *Display of users currently using the system*

D. *Design Evaluation*

The application was evaluated with users in the medical center and people living in the community. During the process of evaluation the participants were given tasks to perform on the different user interfaces. Participants were assigned three different tasks for the evaluation process. The evaluation results are presented next.

a) Tasks Completion Rate

The participants were able to carry out the tasks successfully. The level of tasks completion was very high. The participants recorded 98% tasks completion rate. The participants were able to navigate from one task to the other and from one interface to the other without difficulties. Consistency in the use of Internet and computer facilities has an influence on how well participants successfully use the application. Fourty five percent (45%) of the users were not consistent users of the Internet and computer facilities. Very few of the participants (2%) were unable to complete at least a task out of the three tasks. Fig. 6 shows the graphical presentation of the tasks completion rate. The participants did not find the interactions difficult to understand. Navigating from one screen to another was very simple and also easy to understand.

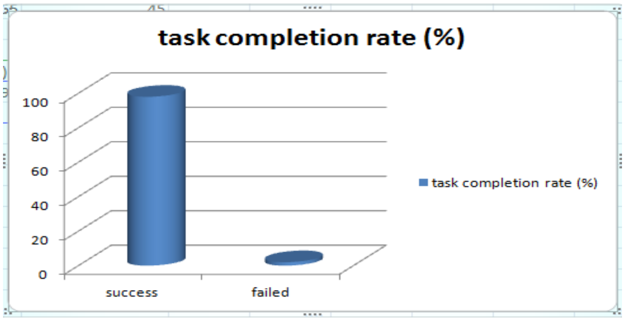

Fig. 6. *Tasks Completion Rate*

The participants used the application with ease and were able to perform and complete the tasks assigned for the process of evaluation. This is an indication that the e-Health VPA application interfaces were easy to understand. The participants who failed to complete all the tasks pointed out that it was due to the inconsistent or no previous use of computer facilities. They also said they were very slow in entering data and the movement of the mouse to the intended location on the screen, also contributed to the failure in completing some of the tasks.

b) Tasks Completion Errors

The participants were able to understand the tasks and were able to navigate from one activity to the other in each of the tasks. Few errors were encountered and higher percentage of the participants performed and completed the tasks without difficulties or errors. Fig. 7 presents the percentage of errors or difficulties encountered by the participants. seventy three percent (73%) of the participants completed the first task without encountering any error or difficulty. 27% of the participants experienced at least one error or difficulty as they performed the first task. Seventy five percent (75%) and 88% of the participants performed and completed task 2 and task 3 respectively without having any difficulty or committing any error. Twenty five percent (25%) and 12% performed and completed task 2 and 3 respectively with at least a single error or difficulty. The result indicates that the e-health application is interactive and easy to use. The users will be able to use the simple, and user friendly interfaces to carry out interactions between patients and medical specialists/caregivers.

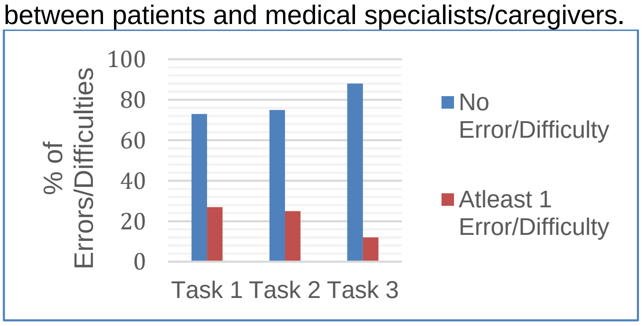

Fig.7. *Tasks Completion Errors*

The interviews conducted at the end of the evaluation sessions reveal that the participants were optimistic about using the e-Health VPA. The medical specialist also feel that the application will help to reduce about half the time spent for consultation with patients and giving prescription will be made simple and faster. The medical specialist agreed that the interactions were simple and easy to complete. The items and elements of the user interface were easy to understand and interact with. The users will be able to interact with the application to achieve the goal of receiving and giving medical care.

V. Post Evaluation Assessment

The post evaluation assessment was conducted to enable the users give feedback on the application they interacted with during and after the evaluation process. The exercise was conducted with users that took part in the evaluation process and some other users who used the application outside the evaluation process. A positively rate likert scale questionnaire was distributed to the participants to complete and then analyzed. The results are presented in table I. The participants agreed that the application provided an easier avenue for both the patients and the medical specialist to contact each other (Q1). The question was positively rated with a mean score of 3.54 and an SD of 0.99. The standard deviation shows that participants were unanimous in accepting that the system made it easy to communicate with the medical specialist or patient. The rating of question two (Q2) was also positive (Mean score = 3.65 and SD = 0.90). The participants agreed that the application will improve patient/medical specialist interactions. Since the users will be able to communicate during and after work hours it will improve interactions and medical attention can be given or received regularly. This is supported by the participants in question three (Q3, Mean Score = 3.83, SD = 0.62). The result in Q4 (Mean Score = 4.25, SD = 0.66) shows that the users did not experience difficulties using the application and user interface. The interface was simple enough for easy understanding and interactions. The participants were very positive that the application will help to reduce cost of getting medical advice (Q7), it will reduce time used for consultation between medical specialist and patients (Q9) and the medical advice they give or receive will be adequate. The results in general indicate that the participants have established that quality of service can be provided or received through the application.

TABLE I. POST EVALUATION ASSESSMENT RESULT

Post-Test Likert Scale Questionnaire, 1- Strongly Disagree to 5- Strongly Agree			
S/N	N = 24	Mean Score	Standard Deviation (SD)
Q1	The application made contact with the patients/medical specialist easier	3.54	0.99
Q2	The application will improve patient/medical specialist interactions	3.63	0.90
Q3	The application will help me to get/give medical attention regularly and easily	3.83	0.62
Q4	It is very easy to use the application and user interface	4.25	0.66
Q5	Using Internet to connect to the application is very easy	3.50	0.71
Q6	To get/give medical advice through the application is adequate.	3.75	0.92
Q7	It is not costly using the system to interact with the patient/medical specialists	3.54	0.91
Q8	The interactions are simple and easy to understand	3.58	0.64
Q9	The application will help to reduce time wasting during consultations	4.33	0.75
Q10	The application response time is adequate	3.67	0.75

VI. CONCLUSION

The application of ICT in the health sector is gaining tremendous attention even in the developing countries. But there are so many challenges that still need to be addressed before people in developing countries can benefit fully from ICT implementations in the health sector. These challenges include lack of computer education, unstable power supply, inadequate computing facilities, and most importantly lack of government policies and regulations towards ICT implementation in the health sector. In the developed countries, ICT is already providing several benefits and it has become an efficient investment in the health sector [20]. During the study, it was found that some health workers are not aware of the use and benefits of ICT in the health sector. There are some people in the work places such as the medical centers or clinics and hospitals that still find it difficult to interact with ICT services [5]. It was also found during the study that Patients' records are still written, analyzed and managed only on hard copy files. These hard copies are subsequently stored and retrieved through tedious search process that passes through volumes of hard copy files if found at all. People who use ICT services in their work place do so without the involvement of the organization they are working for. That is, they pay personal subscription fee for ICT services to enable them carry out their work in the organization. These are all factors that need to be considered when designing user interfaces and interactions for e-health services in developing countries.

The e-Health application developed during this study can help to improve work place efficiency, reduce cost of health care delivery. The agents in the application communicate with each other; in particular cases, the VPAs directly communicate with one another. Messages are sent by the patient to the medical specialist or vice versa, the agents could make inferences and provide feedback. The application will help the patients in reducing the hours they would have spent in the medical center and thereby reduce anxiety. It will increase the medical specialist productivity, reduce fatigue and increase quality of service offered to the patients. The potential users within and outside the medical center were adequately involved in the development of the application. The users' evaluation results show that the users perceived that the application will strengthen regular interactions between medical specialist and patients, time wasting during consultation will be reduced and productivity can be increased. The medical specialists were able to retrieve patients' data in the system and provide medical advice. The patients had access to their medical advice provided by the medical specialist in the system. The users were satisfied with the performance of the application.

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