CONTINUOUS MONITORING OF A CHILD’S HEALTH USING ANDROID APPLICATION

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ABSTRACT

This paper presents a replacement eHealth platform incorporating mechanical man robots to support associate rising three-dimensional care approach for the treatment of polygenic disease. The design of the platform extends internet|the net} of Things (IoT) to a web-centric paradigm through utilizing existing web standards to access and management objects of the physical layer. This incorporates capillary networks, every of that encompasses a group of medical sensors coupled wirelessly to a mechanical man mechanism coupled (via the Internet) to a web-centric unwellness management hub (DMH). This provides a group of services for each patients and their caregivers that support the complete time of the three-dimensional care approach of polygenic disease. The platform’s computer code design pattern permits the event of varied applications while not knowing low-level details of the platform. this is often achieved through unifying the access interface and mechanism of handling service requests through a bedded approach supported object virtualization and automatic service delivery. a totally purposeful image is developed and its end-toend practicality and satisfactoriness ar tested with success through a clinician-led pilot study, providing proof that each patients and caregivers ar receptive to the introduction of the projected platform

Keywords: - *eHealth; Internet of things; multidimensional care; robot-assisted therapy; object Virtualization;*

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1. INTRODUCTION

Prevalence of diabetes is increasing at an alarming rate worldwide. It is estimated that 415 million people have diabetes, every 6 seconds a person dies from diabetes with the accounts for 12% of the global healthcare expenditure [1]. As a result, there has been an increased pressure on the available healthcare resources, and patients diagnosed with diabetes require a more efficient and individualized disease management plan to prevent (or delay) progression and treatment costs of the short- and long-term complications of the disease.

Benefiting from technology advancements and cost reduction in wireless networks and web technologies, numerous electronic/mobile health (e/mHealth) applications [2] - [4] have been increasingly reported in the literature. These applications offered various levels of user interaction intensity; ranging from general information, specific information targeting specific patients, to tailored user feedback information. Authors of these studies generally agree that ICT solutions are effective in diabetes management terms of patient monitoring and technology-based decision support applications but further studies are still needed to assess the effectiveness of technology-based solutions with respect to long-term behavior change support in, adherence and patient engagement with their health careers.

In addition, most of these solutions are focused on the functionality, technological and mobility issues but not on behavioral changes and acceptability challenges of these applications. Continued improvement in diabetes self management and, in particular, type 1 diabetes mellitus (T1DM) in children and adolescents therefore requires a multidimensional care approach that is not only focused on routine diabetes care activities but also on psychological and social dimensions.

The multidimensional care approach of diabetes has emerged in 2010 [5], when a multidisciplinary team combined psychological and social aspects with the traditional primary care of diabetes. Preliminary findings from a clinical trial showed a significant improvement in the blood sugar control in those who engaged in this care approach [6]. However, the requirement of engaging additional physicians is likely to be financially unsustainable in the current frugal economic climate in light of NHS staffing constraints. This is where the incorporation of eHealth technologies to facilitate the seamless and asynchronous interaction between the patients and their caregivers could potentially add a significant value by improving both efficiency and productivity of the care process, while providing a personalized and patient-centered experience.

The Internet of things (IoT) is a new concept associated with the future architecture of applications development in which the physical objects (POs) and virtual (or digital) objects (VOs) are interconnected through various means to enable new application and services. The VOs tend to be smarter representations of the POs through enriching their digital models by cognitive management functions and user information. They also can have several attributes in common. However, based on practical experimentation and prototyping, these objects can be categorized into three types; activity-aware, policy-aware, and process-aware objects. The key differences between these object-types can be identified in terms of awareness, representation, and interaction.

The work presented in this paper suggests a next generation of eHealth platform driven by the requirements of the multidimensional approach of diabetes care and the IoT architectures. It suggests a novel technology support that integrates diverse diabetes care aspects, robotic coaching, wireless technologies and distributed intelligence in a single platform. Incorporation of robots in diabetes management, which is not yet thoroughly explored in literature improves patient-career interactions over a distance and allows for a more efficient and cost-effective implementation of the multidimensional care approach. In the proposed application scenario, the platform is based on policy-aware IoT objects with the following design dimensions:

- *Awareness* – understands to what extent the patients' activities comply with their individual treatment plans.
- *Representation* – applies a set of rules on patients' data streams and extracts useful summaries and health indicators such as blood glucose (BG) patterns, insulin bolus calculation, and patients' categorization depending on attributes of their health conditions.
- *Interaction* – uses accumulated data stored in the patient's electronic medical record to create reminders, warnings messages, and appropriate health advices when self management outcome deviates from pre-specified targets.

2. EXISTING METHODOLOGY AND LIMITATIONS

ICT solutions are effective in diabetes management in terms of patient monitoring and technology-based decision support applications but further studies are still needed to assess the effectiveness of technology-based solutions with respect to long-term behavior change support in self management, adherence and patient engagement with their health careers. In addition, most of these solutions are focused on the functionality, technological and mobility issues but not on behavioral changes and acceptability challenges of these applications.

3. PROPOSED WORK

These applications offered various levels of user interaction intensity; ranging from general information, specific information targeting specific patients, to tailored user feedback information. The platform is based on Policy-aware IoT objects with the following design dimensions:

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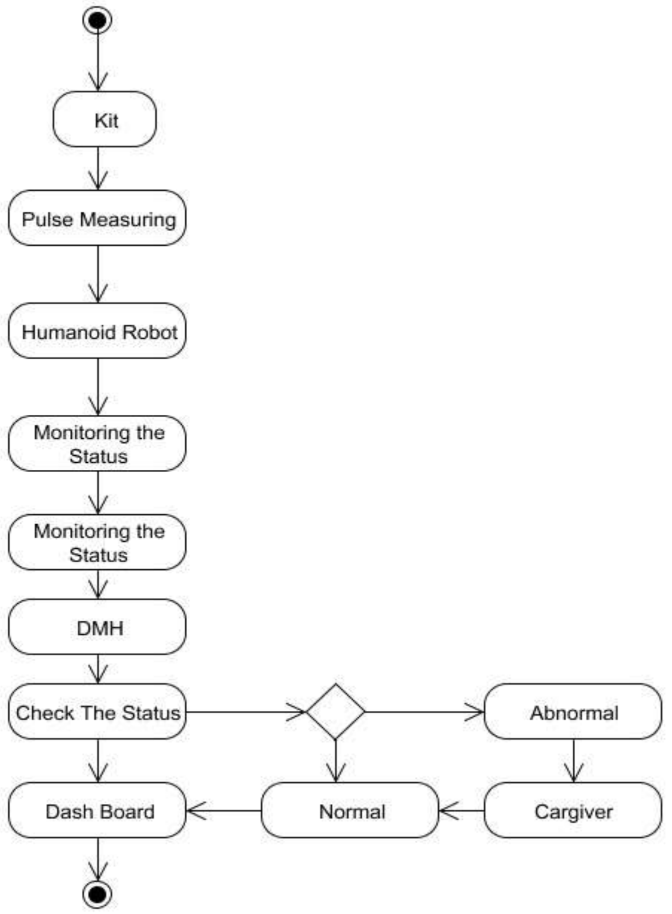

Fig -1 Activity diagram of the proposed method

Figure 1 represents a flowchart that depicts the working of all the phases. The scenario adopted in this paper is an eHealth platform with remote accessibility and manageability of variety of POs. Network architecture of the platform encompasses two main components; capillary networks of the POs and a web-centric disease management hub (DMH) for patients monitoring and disease management.

4. SYSTEM ARCHITECTURE

The design of the platform extends the {web|the net} of Things (IoT) to a web-centric paradigm through utilizing existing web standards to access and manage objects of the physical layer. This incorporates capillary networks, every of that encompasses a collection of medical sensors coupled wirelessly to a mechanical man automaton coupled (via the Internet) to a web-centric unwellness management hub (DMH). This provides a collection of services for each patients and their caregivers that support the complete time of the dimensional care approach of polygenic disorder. The platform's computer code design pattern allows the event of assorted applications while not knowing low-level details of the platform. this is often achieved through unifying the access interface and mechanism of handling service requests through a bedded approach supported object virtualization and automatic service delivery.

Software development of the main platform components (i.e. the robot and DMH) is unified and logically divided into three main components; system, database, and applications. The components are shown in Fig. 2 and are described briefly as follows:

1) *System* – refers to the core classes, configurations and service libraries that provide a skeleton and a container for various applications at both the robot and the DMH.
2) *Database* – represents both local and centralized storage for the robots of the capillary networks and the DMH, respectively.
3) *Applications* – refer to the modules that handle POrelated functionalities including human objects.

Design of all application modules at both the robots and the remote DMH are compliant with the Model-View-Control (MVC) architectural pattern that provides a practical solution to separate the user interface (view) from the data (model). In this pattern, the view interacts with the model through the controller that mediates the input and converts it to commands for the model or view.

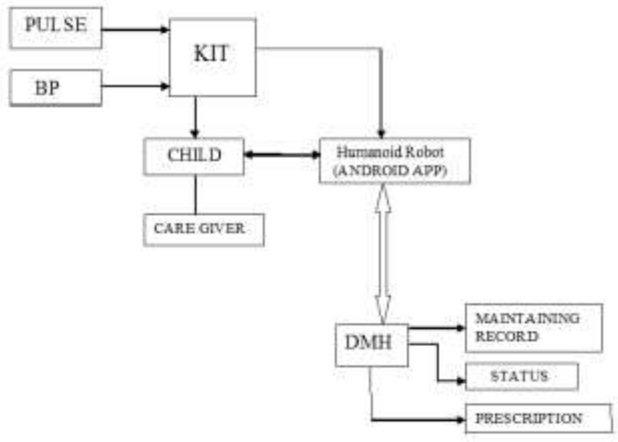

Figure 2. Architecture of the system

This logical division of the applications development improves interlayer operability, software reusability and maintainability across the platform [7]. It also enables the developers of IoT applications to develop various applications without the need to know low-level details of the platform.

B. Object Virtualization

Virtualization of the POs is a key requirement for IoT infrastructure. It enables digital representation of objects and acts as an interpreter between the physical and the virtual layers of the platform. A layered object-virtualization approach [15], [16] is adapted in this work to ensure interoperability and reusability of VOs. A two-stage virtualization process is carried out at the robot and the remote DMH to provide digital representation for all PO of the proposed platform.

1) *Robot's virtualization* – the robot virtualizes all real- world (or physical) objects in the associated capillary network (i.e. the patient and his/her medical sensors). The VOs provide semantic descriptions for the associated POs using a unified structure for both the device and human objects. This enables efficient data exchange between different types of objects through specifying the data and its relationship among other objects. As a result, the POs can be accessed through their VOs, which in turn act as translators between the digital and physical worlds.
2) *DMH's virtualization* – the DMH virtualizes the robot objects of different capillary networks as well as other user objects (i.e. caregivers and technical support staff) are virtualized at this stage. Unlike the robot virtualization where each VO is constrained by the capability of the associated PO, more complex

VOs, called composite VOs (CVOs) are required at this stage to represent the case where multiple VOs collaborate to accomplish a particular task. For example, the physician VO needs to collaborate with the medical sensor VOs to create and deliver a warning message/advice to the patient when the disease management outcome deviates from a pre-specified target. Semantic features of such a CVO describe its capabilities and relationships with other objects and thus help locating suitable objects that can respond to a certain service request.

5. IMPLEMENTATION

The following are the various modules of the system:

DMH (Disease Management Hub):

The Patient profile creation is used to add the patient information to a server and then add the respective kit id. The server maintains the patient information and updates the status of a patient. The kit is used to sense the patient’s pulse and blood Pressure.

The web application represents a single-page summary for the patient and the caregivers. It also provides access links to all key platform applications such as treatment plan, BG patterns, and other applications. For the patient, it summarizes the health profile through monitoring patient’s vitals and trends of bio-data, pediatric summary and medical summary. For the caregivers, it displays patient’s icons that are hyperlinked to the corresponding patient dashboard. These icons are colored red, yellow and green to reflect good, acceptable and poor disease management performance. This saves time and helps the caregivers prioritizing their efforts accordingly.

Creation and Allocation of Virtual Objects:

Virtual objects (VOs) of the DMH are capable of interpreting events and activities with respect to predefined healthcare policies/guidelines in terms of awareness, representation and interaction. For instance, these objects understand to what extent the patient’s activities comply with the treatment plan/guidelines, apply rules on patient’s data streams to extract useful summaries, and use accumulated data to create appropriate warning messages and advices to the corresponding objects at the physical layer.

Interactive Humanoid like Response System.

This system performs all kinds of verbal robot patient interactions. It allows for collection of verbal information concerning the patient’s diet and physical exercise as well as recording patient’s audio messages to his/her caregivers. It also manages presentation of various dialogues assigned to the patient by his/her physician to enrich the interaction by making it more natural. It allows new users to register their robots medical devices using unique identifiers (e.g. serial numbers) as well as a security token that is randomly generated by the robot upon its first use. The device identifier and security token number are used to encrypt and decrypt data exchanged between the robot and DMH. The patient, as necessary, can then maintain his/her profile. Once registered, the patient will then be assigned to a professional caregiver, depending on his/her health status.

Monitoring the child status:

The medical sensors are linked to the Humanoid Robot (Smartphone in our application) through a personal area network in which the robot acts as a master Bluetooth device, as illustrated. The robot at each capillary network also acts as a conduit between the patient and his/her medical sensors from one side and the DMH and caregivers from the other side. The DMH provides a set of services that cover the full continuum of diabetes management for the patients and their caregivers.

The long-range connectivity between these components is performed through a wireless local area network (Wi-Fi) linked to an existing network infrastructure (the Internet). Each capillary network comprises a set of medical sensors (blood pressure & pulse rate monitor), and an existing humanoid robot.

6. RESULTS AND DISCUSSIONS

Numerous test scenarios have been carried out to assess data quality and end-to-end functionality and a seamless, secure and accurate data exchange has been demonstrated between different layers of the platform. In this section, some key aspects of the developed eHealth platform are presented and discussed.

A. Patient Monitoring

A sample screenshot for the DMH dashboard that provides a single-page summary for patient's health profile is depicted in Fig. 7. It also provides access links to all key platform applications such as treatment plan, dialogue wizard, diabetes diary, BG patterns, and other applications, as illustrated. The primary design goals, which included the automaticity of remote data collection, monitoring of patients data, and maintaining continuous interactivity between the patients and their health careers have been accomplished. It was also demonstrated that the platform understands to what extent the patients comply with their individual treatment plans. DMH's ability to extract various BG patterns and generate appropriate feedback to patients when their health conditions deviate from specified targets has also been demonstrated successfully.

Figure 7. Sample screenshot of the DMH dashboard

B. Patient-Robot Interaction

Patient-robot dialogues support patients' empowerment and motivation towards healthy lifestyle and improved BG control. These dialogues are created by specialist clinicians and saved into a dialogue library at the DMH that is made accessible to all caregivers. The dialogues in this library can be assigned to patients as required, depending on their individual needs to support the disease management process.

C. Data Quality

Data quality (DQ) has been described in the literature with multiple dimensions. However, there is no consensus on a rigorously defined set of dimensions [24]. In the developed platform, the DQ is facilitated by (i) accurate identification of the patients and their devices, (ii) implementation of health related DQ dimensions (i.e. accuracy, completeness, consistency, timeline and usability), and (iii) data transmission integrity. Implementation of these mechanisms is described briefly as follows.

1) *Patient/device identification* – this mechanism is performed at both the local capillary network and the remote DMH. At the local network, the robot identifies the patient either through a face recognition facility in the robot or by identifying a key that is randomly generated by the robot upon its first use. Upon successful identification, the robot starts interacting with the patient and enables Bluetooth connectivity with the medical devices. Similarly, the robot attempts to establish a connection with the remote DMH using the same key subject to its pre-registration at the patient's profile. If successful, the DMH server returns a unique identifier (ID) for the robot that is used in all future communications across the platform layers. This ensures that the patients' profiles match the patients by cross-layer IDs.
2) *Health-related DQ dimensions* – once the data collection process completes, the robot summarizes the collected data to the patient to verify (i) its conformity with the actual readings of the medical devices (i.e. accuracy), (ii) none of the anticipated data is missing (i.e. completeness), and (iii) the collected measurements are consistent with the actual readings of the medical devices (i.e. consistency), and to obtain verbal consent prior to sending them to the remote DMH. At the DMH, the data elements that do not match the patient's health profile or historical data are filtered by presetting certain threshold for each data source beyond which the data is considered abnormal. Each of the data elements is also time-stamped to enable its storage in a chronological order to facilitate its availability on time.

D. Acceptability

A pilot clinical acceptability study was conducted with the aim of exploring how young diabetics and their caregivers receive the proposed platform. The study also aimed to determine how the patients feel the robot, as a new medical device, may contribute to their care, and how they respond to the advices and education provided by the robot. The study also investigated how the robot serves as a communication device between patients and health care professionals. A total of 22 patients equally divided between males and females (8 to 15 years old) with T1DM and 7 clinicians (4 diabetes consultants, a nurse, a dietitian, and a diabetes technician) participated in this study. Acceptability of the platform was measured in terms of the following four specific services (S1 – S4) that were considered of interest to both the patients and their caregivers.

The obtained results showed a relatively high acceptability level, as shown in Fig. 9. These results as well as the positive comments received from the patients and their parents have been promising. A wider and more detailed study of the feasibility and acceptability of the platform are recently reported by the authors in [26], [27]. Unlike other existing e/mHealth platforms, which are mostly focusing on mobility and remote patient monitoring, design and architecture of the proposed platform is driven by several key emergent healthcare requirements and technology developments, in particular:

- It supports multidimensional care approach that integrates social and psychological care with the traditional primary care of diabetes in a single platform without imposing financial burden on the NHS budget.
- It responds to the growing need to conduct social and behavioral studies to address adaptability challenges of diabetics with their health careers and families.
- It is based on the IoT architecture that can addresses the challenges of developing the next generation of a personalized delivery of healthcare services and potentially reshape some of the current healthcare delivery systems and relevant services.

Developing such an innovative platform is expected to dramatically improve diabetes care through (i) supporting long-term behavioral change from unhealthy to healthy lifestyles, (ii) delivery of cost-effective healthcare services over a distance, and more importantly (iii) improving BG control in children and young adults.

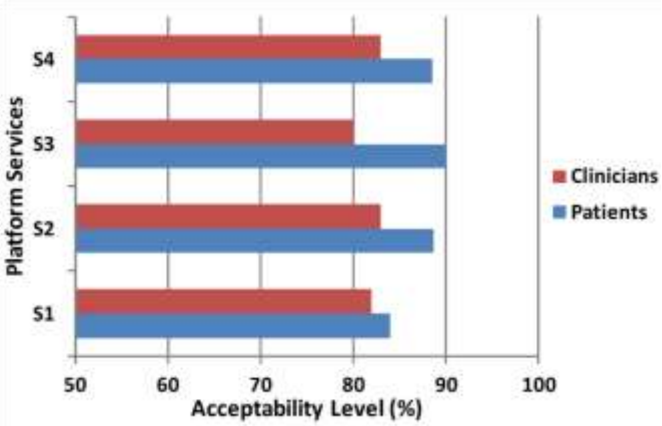

Figure 9. Patients and clinician acceptability of the eHealth system

7. CONCLUSION

A fully functional IoT-based eHealth platform that incorporates humanoid robot assistance in diabetes management in children has been designed and developed successfully. This is achieved through an intelligent, adaptable and reconfigurable process of participatory design in which patients are heavily involved in creating their personalized health profile, follow-up and treatment plans. The developed platform facilitates a continuous but loosely coupled connectivity between patients and their caregivers over a distance and thus improving patients' engagement with their caregivers and minimize the cost, time and effort of the traditional periodic clinic visits. This will also contribute to long-term behavioral change from unhealthy to healthy lifestyles.

The end-to-end functionality and data quality of the developed platform were tested through a pilot clinical acceptability study. The suggested architecture and applications can also be considered a blueprint for developing a generic eHealth platform for management of various chronic diseases other than diabetes. This platform is therefore remains open for further technical improvements and clinical studies. In particular, the virtualization approach and semantic representation of POs that tackles the heterogeneity challenge of the platform can be further improved through enhancing the cognitive capabilities of the VOs. This approach can be adopted to realize a more flexible patient-robot dialogues. Further clinical studies are also required to assess the impact of the proposed technology on the quality-of-life of young diabetics. The implemented mechanisms for data quality can also be further improved by using an advanced patient-profile matching through probabilistic algorithms, as needed.

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