Journal of Engineering and Applied Sciences 12 (19): 4856-4861, 2017
ISSN: 1816-949X

Smart Mobile Healthcare System Development for Patient-Doctor Interaction and Self-management

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Abstract: We have developed a smart mobile healthcare system to improve patient-doctor interaction and to promote the self-management of chronic diseases by the patients themselves. Chronic diseases will become the most expensive diseases faced by the current healthcare systems and the integration of prevention into healthcare is the main solution for this problem. The introduction of self-management by patients with a chronic disease seems inevitable as a countermeasure against these developments. The smart mobile healthcare system provides intelligent, user-friendly and secure, medical and well-being decision support through embedded software in mobile devices by utilizing specific sensors and data from customized information systems.

Key words: Healthcare, chronic disease, telecare, self-management implementation, smart mobile, support

INTRODUCTION

In the healthcare sector, smart system technology leads to better diagnostic tools, better treatment and a quality of life for patients by simultaneously reducing costs of public healthcare system. Smart healthcare is an upcoming discipline that involves the use of information and communication technologies including both hardware and software solutions and services. Generally, smart healthcare is concerned about the development of interconnected health systems so as to improve the use of computational technologies, smart devices and communication media. Smart healthcare is also helpful for healthcare professionals and patients who manage illnesses and health risks as well as promote health and wellbeing (IODH, 2013). So, a smart healthcare is a multi-disciplinary domain which involves many stakeholders including clinicians, researchers and scientists with a wide range of expertise in healthcare, engineering, social sciences, public health, health economics and management (Hawley, 2017).

For solving the chronic disease problems, a paradigm shift toward integrated and preventive healthcare as well as equipping patients with information, motivation and skills in prevention and self-management are described as essential elements. Systems that collect information from a network of on-body and ambient sensors are a promising tool for such solutions (Chen *et al.*, 2011; Pervez *et al.*, 2009; Neves *et al.*, 2006). Combined with the additional information of the user's surroundings via ambient sensors, health monitoring solutions can be built to face these upcoming challenges in healthcare systems. The proposed system is developed for considerable and measurable advances in the intelligent healthcare for patients with chronic diseases.

MATERIALS AND METHODS

Healthcare technology: The Smart Mobile Healthcare System (SMOHS) develops remarkable and measurable advances in the intelligent healthcare system solutions and the advances, contributing measurably to more effective healthcare and more cost-effective medical practices including especially better user-friendliness, increased intelligence, better understanding on the balance of privacy and security, increased context awareness of healthcare applications and increased interoperability with health information systems.

User-friendliness: Health technologies that cut off many potential users because of poor design resulting in poor usability and accessibility must be avoided. Patients will

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be accessing the SMOHS from a variety of devices and for an even higher set of medical conditions. The necessity for relevant and fast choreography with in processes as well as orchestration of processes will be important. The fact that many recipients of health services are elderly necessitates a focus on usability and accessibility given that elderly persons are less experienced using Information and Communications Technology (ICT) and may also have specific physical or cognitive issues impeding on their ability to use ICT.

Moreover, persons with chronic conditions such as diabetes may have specific functional problems because of their illness. Persons with diabetes may for instance have reduced vision and reduced sensations in their fingertips adversely affecting their ability to operate health technology. Many people-especially elderly-shy away from smartphones and opt for more basic phones with less functionality. This adds a challenge as many of the elderly users may be skeptical to smartphones. This further necessitates the development of easy to use smartphone applications and set ups which do not alienate potential users. To counteract the above discussed potential for exclusion this study takes a user-center approach focusing on design for all and good usability in all the interfaces that are operated either by patients/users but also by health staff and other careers.

Intelligence: Intelligence of healthcare applications are in focus in the monitoring, management and distributed control entities of all stakeholders involved in order to make them cognitive and self-adapting. Real-time feedback and improved communications to the network of care are amongst others the main features of intelligent mobile self-care applications. In the assistive environment of a patient a lot of tasks, like monitoring, maintenance, routing, management, etc., will also have to be distributed among network entities and techniques like distributed intelligent agents could also envisioned. Make all those entities cognitive/autonomics implies to be able to:

- Learn, model and predict the behavior of objects (process/component, patient, data, context data, environment, sensor and device) with the associated risk factor
- Assist decision making by identifying their states and status and have all the conditions within SMOHS intelligent units
- Enforce the corresponding policies, rules and parameters, in accordance with patients, self managing functionality and caregivers in actuators and decentralized control units

A general approach for smart and cost-efficient analysis of data for mobile healthcare applications is still an open issue. In this context, two different analyses of mobile data can be considered on the device and in the backend. A combination of both is expected to provide the required quality and efficiency for healthcare applications.

Reliability and energy consumption: The main issue of analysis on the device is limitation of resources (e.g., battery or memory). In this context Ubiquitous Data Stream Mining (UDM) can perform real-time analysis on a mobile device while considering available resources. In healthcare sensor devices, reliability, latency and energy consumption are all important requirements and will be advanced in a measurable way. Application requirements should be communicated to the physical layer protocols in order to adapt to the given situation such as in an emergency where low latency and high availability are of paramount importance. In other situations, the status of battery lifetime and correspondingly how to extend battery-life become important. While several event-driven technologies and message formats have been proposed, there is still the lack of understanding and connection between emergency and measurement data concerned event mechanisms. Especially, to cope with the intrinsic security and privacy issues which arise from the introduction of data-filtering on the need-to-know basis when different stakeholders are included in the process of care, support and tele-medical solutions are a challenge.

Security and privacy solutions: The privacy-preserving crypto protocols (i.e., zero knowledge protocols and noisy crypto protocols) and algorithms (i.e., homomorphic encryption schemes and multi-party computation) are developed. The solutions are developed utilizing risk-driven security and privacy objectives analysis and assured using a sufficient and credible set of security and privacy metrics. The metrics will emphasize security and privacy effectiveness of utilized security and privacy solutions.

Context awareness: The work carried out improves the context-aware decision-making support of healthcare application by providing means of defining and evaluating Quality of Context (QoC) thresholds at sensor, context management and application layers. In additional, this work provides standardization for QoC control in healthcare systems.

RESULTS AND DISCUSSION

Smart mobile healthcare system: The SMOHS architecture is shown in Fig. 1 and which is composed of

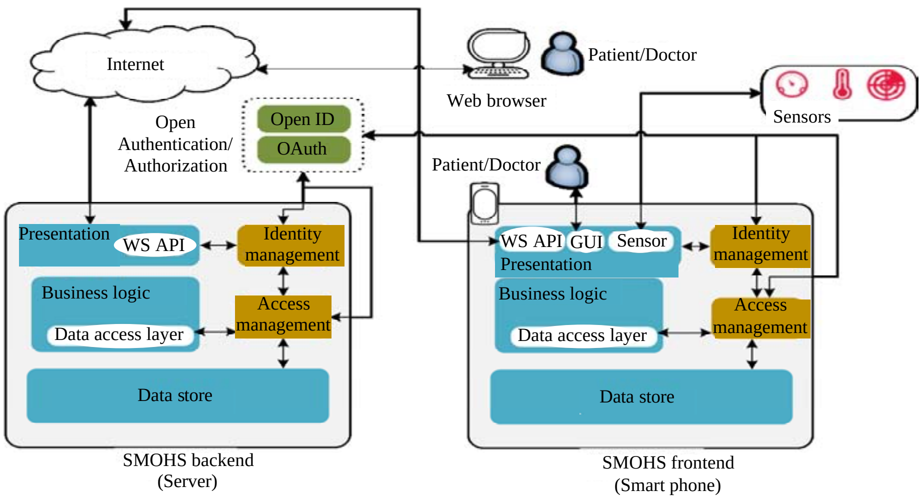

Fig. 1: SMOHS architecture

frontend (right) and backend (left). The frontend has mobile devices, medical sensors, environmental sensors etc and the backend has a server and a database. Using this architecture, each user case architecture is developed along the functions of sensing, reasoning, alarm and recommendation, etc.

Architecture: For hypertensive patients, the system is developed. In the frontend, information such as treatments or activities to affect the blood pressure, measurement data of their blood pressure levels several times a day, etc., is collected automatically or manually. The collected data is analysed in the Smartphone and the results are transferred to the backend server. In the backend, doctors can check the patient information and data related to blood pressure from the backend server and transfer their medical opinions through the backend server. For the interconnection between the backend server and outside medical systems, the standard protocol such as Health Level 7 (HL7) is used (Richesson and Krischer, 2007).

Security: For the security of privacy and personal information, this study applies identity management and access management. The requirements of the security are defined in Table 1 and based on this table, the security architecture is developed. In the security architecture to satisfy the requirements, the identity module manages user accounts and the access module manages accesses by user rules. For the effective and secure protection of the user identity, the developed security module defines the identity level, identification method, storage location and the standard certification such as OpenID, OAuth for each user case and also the security module is implemented to be able to apply the identity in the outside system such as social network for the certification.

Table1: Security requirement

Requirements	Description
Data security	Protect accidental or unlawful destruction or accidental loss, alteration, unauthorized disclosure or access
Privacy	Concerns of personal data misuse
	Tampering with medical data has many obvious risks; even the ability to read confidential data carries risks
	Develop highly sophisticated methods to protect patient credentials
Trust	Data trust and integrity can be achieved in large parts by adding cryptographically strong checksums to the data
	Error-correcting codes are entirely insufficient as they only protect against accidental modification

For the prevention of an unauthorized access by unnecessary users and the protection of the personal information, the security module controls the accessibility by the predefined rules which define the patient and the doctor who can access the data. Even if a new user is registered, this module can control by a group because of the rules without separately managing the rights for each individual.

Smartphone application: The developed Smartphone application has major functions including:

- Data collection such as blood pressure, heart rate by the sphygmomanometer over the wireless communication (HDP: Health Device Profile)
- Automatic collection of exercise data by wireless communication
- Automatic and manual input of data related to the hypertension (exercise, treatment, blood pressure, heart rate, etc.)

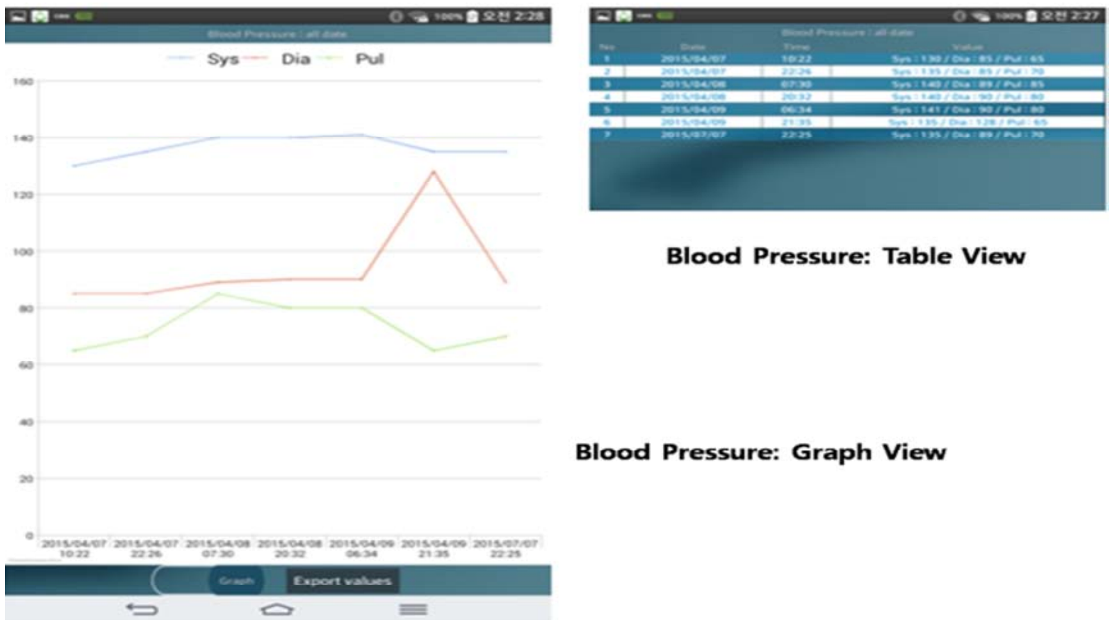

Fig. 2: Graphic and table view

- Smart blood pressure management along the user-defined blood pressure level
- Communication with backend server for information transfer (transceiving data/receiving doctor's opinion)
- Analysis of the blood pressure data by reasoning method based on the rule
- Event registration and notification for blood pressure measurement
- Table view and graphic view for blood pressure data as in Fig. 2
- Export of blood pressure data
- Emergency management

The wireless communication is Bluetooth HDP between the medical device and the smartphone. Personalized rules for each user are applied. These rules are used for notification to the patient when the patient breaks the rules which is predefined about blood pressure, treatment and exercise by the doctor and the patient. The basic algorithm of the rule-based reasoning method is shown in Fig. 3 and evaluates the measured data by if-then rules.

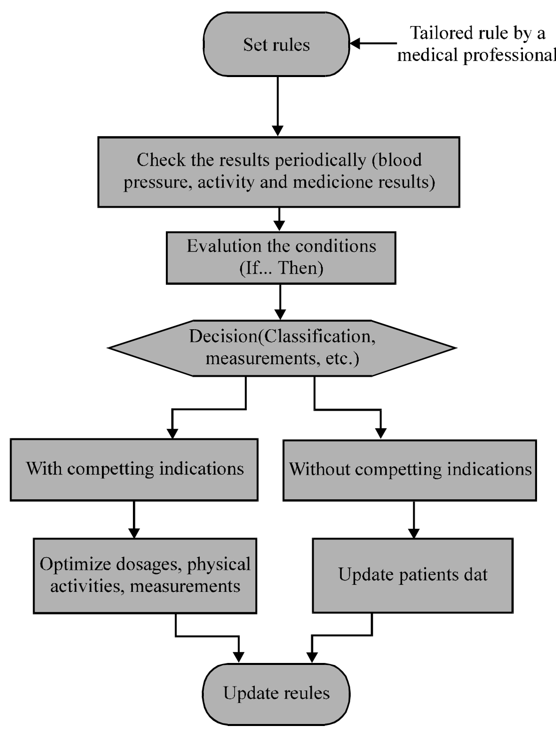

Fig. 3: Rule-based reasoning

Server application: Hypertension management app transfers the collected data to the backend server through the smartphone and the data also can be managed through the connection via the web. Through the web, blood pressure, exercise, treatment, etc., can be viewed by a graph and a table as in Fig. 4 and functions such as reasoning and alarm are not provided for the web application. When the authorized doctor accesses, the

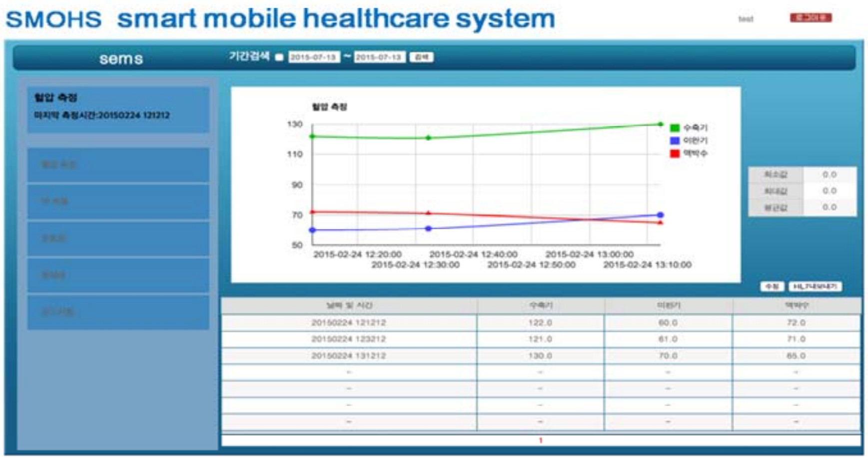

Fig. 4: Web application (in Korean)

doctor can review the allowed patient information and data and if necessary, the doctor can send a message to the patient. Also it is possible to exchange the patient information and data between the backend server and the outside system through the standard protocol.

Evaluation: The usability and reliability of mobile health systems are key factors in their acceptance and adoption for long-term use by the users in disease self-management. To guarantee these properties, a thorough evaluation of each system's components (hardware and software) is required which involves multiple testing phases. This process usually starts by testing the individual components (for example, use of sensors, mobile device operation, manual data entry) then moves on to integrated testing to check whether or not the different components work together as intended (for example, data transmission, networking) and finally by performing field tests with the users in the environment for which the system was actually designed. During the first two phases, formal methods such as model checking and program verification, may be applied for example to prove the absence of deadlocks. During field testing, evaluation is done by a randomized clinical trial where each patient is using the same system but for half of the randomly selected patients the system will have no effect on the management of the disease in such a way that the system does not provide any effective feedback to those patients while for the other half of the patients the system will indeed give such appropriate feedback.

As many mobile health systems guarantees can be given that they will never be harmful to the patient, evaluation amounts to determine whether the originated intervention is effective, i.e., that it contributes to improve healthcare by comparing standard care results such as the number of patients that are admitted to a hospital each year. If the number of admissions had dropped for patients who used the mobile health system, then there would be clear evidence that the system would have been effective.

Before an actual field test can be started, insights are needed regarding the usability, reliability and user-friendliness of the system because if the system fails to meet reasonable requirements regarding these aspects, carrying out a proper field test will be a clear waste of time. Therefore, before any field testing is carried out, usability tests will be performed with future users, subsequently obtaining feedback through questionnaire. The feedback will not only report on issues with the technical operation of the system but it will also relate to usefulness and added value in terms of self-management, confidence and willingness for a continuous usage of the system. A usability test may also help pinpoint issues that need to be worked on to improve the system.

CONCLUSION

The development of smart mobile healthcare system involves various research challenges, many of them technical while others concentrate on the stakeholders, such as the end-user and society as a whole (Adewale, 2004; Istepanaian and Zhang, 2012; Rodriguez *et al.*, 2013; Kamal *et al.*, 2012). In this study, these challenges are addressed by well-chosen use cases that cover a wide range of current and future applications of smart mobile technology. This study covers the main issues that must be tacked for the successful development and deployment for such systems.

ACKNOWLEDGEMENTS

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. NRF-2015R1D1A1A01059060).

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