A SMARTPHONE APPLICATION FOR CHRONIC DISEASE SELF-MANAGEMENT

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Abstract

Most mHealth solutions rely on an architecture that only addresses one specific disease and are usually either all-online or all-offline. This report presents the results of our research on the creation of an interactive, intelligent and secure mHealth solution that can also contribute to the improvement of patient/carers interaction. A dual architecture, developed both on a back-end and locally on a smartphone, allows to combine the computing and memory capability of a powerful computer with the flexibility of an offline application. It is also aimed to develop a global architecture for a single mHealth solution that addresses a group of chronic diseases. This requires taking into account the diversity of sensors, data formats, algorithms and scenarios. To illustrate the usefulness of such architecture, we describe its usage for the case of diabetes. Our solution relies on decision-making embedded software, utilizing medical sensors for mobile devices and information systems.

Keywords

m-Health, Chronic diseases, Blood Glucose Monitoring, Telemedicine, Self-management

I. Introduction

Chronic disease are spreading at an ever faster rate, due to the global ageing of the world's population. Diabetes mellitus alone rapidly evolves as a global pandemia. It is estimated that the number of people with diabetes will exceed 550 million by 2030 [1]. Currently, there exists two main therapeutic approaches for the treatments of diabetes mellitus which aims at stabilizing the blood level of glycated hemoglobin (HbA1c):

• The classical insulin therapy consists in regular insulin intakes at fixed hours with determined doses.

• The functional insulin therapy allows patients to adapt their treatment to their lifestyle by increasing or decreasing the calculated insulin dose taking into account extra meals, fasting or physical exercise, to name a few.

Meanwhile, the widespread use of smartphones and other connected devices is currently revolutionizing health-related practises. By 2017, the use of smartphones for health monitoring is expected to spare around 99 Billion euros for the European Union's (EU) healthcare systems and increase the EU's GDP by another 93 Billion euros. [2]

More specifically, patients with type 1 diabetes have recently been offered the possibility to monitor their glucose level through smartphone and tablet applications available on different platforms. For instance, *iBGSTar*, a blood glucose meter, can exchange glucose levels with an iPhone. An iOS application then displays these levels over a period chosen by the user, together with the limits of hypo- and hyperglycemia and the recent carbohydrate intakes. The user can edit reports and send it to the physician. The competitor Diabéo, developed by Voluntis (IT Company) in partnership with CERITD, sanofi and a scientific board, is expected to enter the market soon. It provides, on top of glucose monitoring, a bolus assistant for functional insulin-therapy, an online portal to connect patients with their doctors and a telecare service with nurses. Finally, Actelin is an independent software available on iOS and Android and developed by ACTIMAGE (IT Company) in collaboration with the CEED. Actelin relies on the concept of functional insulin therapy and uses an algorithm to provide users with an insulin and carbohydrate advice.

The current state of the art has already brought glucose monitoring to a high level of modernity and increased the reliability of the collected data. [3].

In this context, a European consortium of experts from universities and SMEs combined their efforts in an ITEA2 project called MoSHCA, MoSHCA is a mHealth project designed to improve the patient-doctor interaction and control for a wide spectrum of chronic diseases and use cases [4].

In this article, we propose an innovative architecture that describes the interactions between users, medical personnel and their tools to improve the current state of the art of self-management of chronic diseases and extend its use to all types of diabetes. We begin with a description of the new use cases that incorporate the above-mentioned improvements. We continue with a listing of the adequate technical solutions. Finally we present an architecture that links all items together.

II. Use Cases

The MoSHCA diabetes application aims at allowing a more flexible and reliable management of the disease by adapting the insulin and carbohydrate advice to the patient's lifestyle. Anywhere and at any time, the users should be able to manage their treatment and to improve it. The system should also improve the interaction between the doctors and their patients.

Therefore, the MoSHCA diabetes application makes use of the functional insulin therapy approach and takes into account the specific needs of each type of diabetes. The following use cases describe the corresponding scenarios.

Scenario 1 – Type 1 diabetes: insulin dependent diabetes (pump & pen)

Type 1 diabetes is treated by daily injections of insulin. The MoSHCA diabetes application will propose an advanced logbook for lifestyle monitoring based on the functional insulin therapy.

Type 1 diabetes patient need to have a strict nutritional diet, they need to control their weight, do physical exercises, avoid smoking and reduce their alcohol consumption. The application delivers an advice on the insulin dose, taking into account the blood glucose level, meals and physical activities. It gives a reminder to the patient regarding their drug intake and helps them to calculate their carbohydrate needs.

Scenario 2 – Type 2 diabetes: non-insulin dependent diabetes

Type 2 Diabetes represents more than 80% of the diabetic population. The treatment is based on dietary hygiene measures, oral drugs, GLP1 hormonal intake and insulin in last intention. The therapeutic strategy is based on the gap with the HbA1c objective (target: ≤ to 7%). Type 2 diabetes is a complex pathology with multiple related health threats such as an increase of cardiovascular risks, high blood pressure and a high level of lipid-cholesterol. The therapeutic education is essential to the management of non-insulin dependent diabetes.

With MoSHCA application, the patient can manage himself using daily a logbook to follow up some parameters (drug and GLP1 hormonal intake, blood glucose level, blood pressure, etc.). The application will deliver an advice related to each of these factors.

Scenario 3 – Gestational Diabetes

Gestational diabetes happens during the second or third trimester of pregnancy and usually goes off after the birth. Treatment for gestational diabetes aims at keeping blood glucose levels equal to those of pregnant women who do not have gestational diabetes. It may include daily blood glucose testing, insulin injections, special meal plans and scheduled physical exercises.

In this case, the patient is a pregnant woman who uses the application to monitor her gestational diabetes. On top of the logbook features described above (blood glucose, meal and exercise monitoring), she can also display all her gynecologist, diabetologist and nutritionist appointments.

Scenario 4– Diabetes telemonitoring

This use case is dedicated to the medical personnel (doctor, diabetologist, nutritionist, etc.). If a patient accepts to be monitored by his doctor, he can allow the access to his data for specific doctor.

On the MoSHCA health platform, doctors can follow several patient statistics and access patient details (address, phone number, etc.) in order to deliver remote advice such as meal planning based on their patient reports. If needed, doctors can schedule physical and virtual appointments or can phone directly the patient in case of emergency.

III. Technical solutions

The implementation of the MoSHCA solution requires several technical devices for the measurement, monitoring and reporting of the disease status. For diabetes, the patient will have to be equipped with a glucose sensor. Several solutions already exist on the market. A few of them have a Bluetooth connection (Glucolog) or can be connected by Wi-Fi (cellnovo, iHealth's wireless smart gluco-monitoring system) or can be plugged directly on the smartphone (iBGStar). The glucose meter must be a certified medical device and have the CE marketing label to be used in Europe.

An estimation of physical exercise can be provided by sensors such as wristband. *Fitbit Flex*, *Jawbone Up* and *Fuelband* are the most common successful wristbands. *Flitbit Flex* uses Bluetooth Low Energy (BLE) for data communications while the competitors use jack ports or regular Bluetooth. BLE is intended to provide considerably reduced power consumption and lower cost, whilst maintaining a good communication range. Moreover, *FitBit Flex* is available on *iOS* devices and Samsung Android devices which support BLE. It covers fewer devices than others because of the BLE Technology but it allows people to have instant communication with their phones and provides a good battery life from 5 to 7 days.

The data must then be collected by smartphones. Many technologies already exist to manage communication between smartphone and other devices and sensors, such as Wi-Fi, BLE, FM Radio and Near-Field Communication (NFC), which is based on existing radio-frequency identification (RFID).

We chose to focus on Bluetooth and Wi-Fi, as they present many advantages. Bluetooth is a low energy technology, known for its speed, and is rather widespread. Wi-Fi is a certification which deploys a local area network for client devices. Its deployment is then a lot cheaper than the other technologies. Moreover, Wi-Fi network adapters can be found on most laptops. Bluetooth, on the other hand, is part of most common wireless technologies in the world.

The communication of medical personal data obeys strict rules and standards. The most common ones are Health Level 7 (HL7), Personal Health Record (PHR), and Clinical Document Architecture (CDA). HL7 is a non-profit organization providing a framework for the exchange and retrieval of e-health information. The 2.x versions of the standards are the most commonly used in the world. A PHR is a health data record which is maintained by the patient himself. This approach allows the system to store complete and accurate data concerning the patient. These data can be passively collected from a smartphone. Finally, the CDA is an XML-based mark-up standard created by the HL7 organization. This standard defines the encoding, structure and semantics of clinical documents required for the data exchange. The second release of CDA has been included as an ISO-standard.

We must comply with these standards in order to maximize our application interoperability and quality.

IV. Architecture

For each use case and each scenario we proceeded to a survey to know what the mandatory needs are. Then we develop an architecture that can fulfil them all. Figure 1 shows the global architecture which can address eight different use cases: diabetes (Type 1, 2 and gestational), chronic obstructive pulmonary disease (COPD), premature babies, risky pregnancy, mobility rehabilitation, hypertension, epilepsy and diet/fitness. The architecture presented in Figure 1 describes the interactions between the users, the doctors and their devices. It is the result of a trade-off between an all-offline and an all-online application. All-offline applications are often memory intensive while all-online architectures restrict the use of a service to the access of a good internet connection. [5] Our architecture therefore consists of two distinct parts: one on a back-end and one on the smartphone. Although with similar logical components, these two parts are implemented differently. Each module can be adapted to suit the expected scenario's requirements and permit the use of such application in case of Internet interruption.

The user is equipped with a smartphone and the sensor corresponding to the pathology he wishes to self-manage (e.g. a glucometer in the case of a diabetic person). Once the measurement is complete, the glucometer wirelessly sends measured data to the smartphone. The smartphone application can get input manually and from the sensor. Data from sensors are temporarily stored in the smartphone database and synchronized daily with a more secured and more voluminous database on the Back-end.

The processing of the data occurs at two different levels: (i) an evolving complex reasoning engine on the

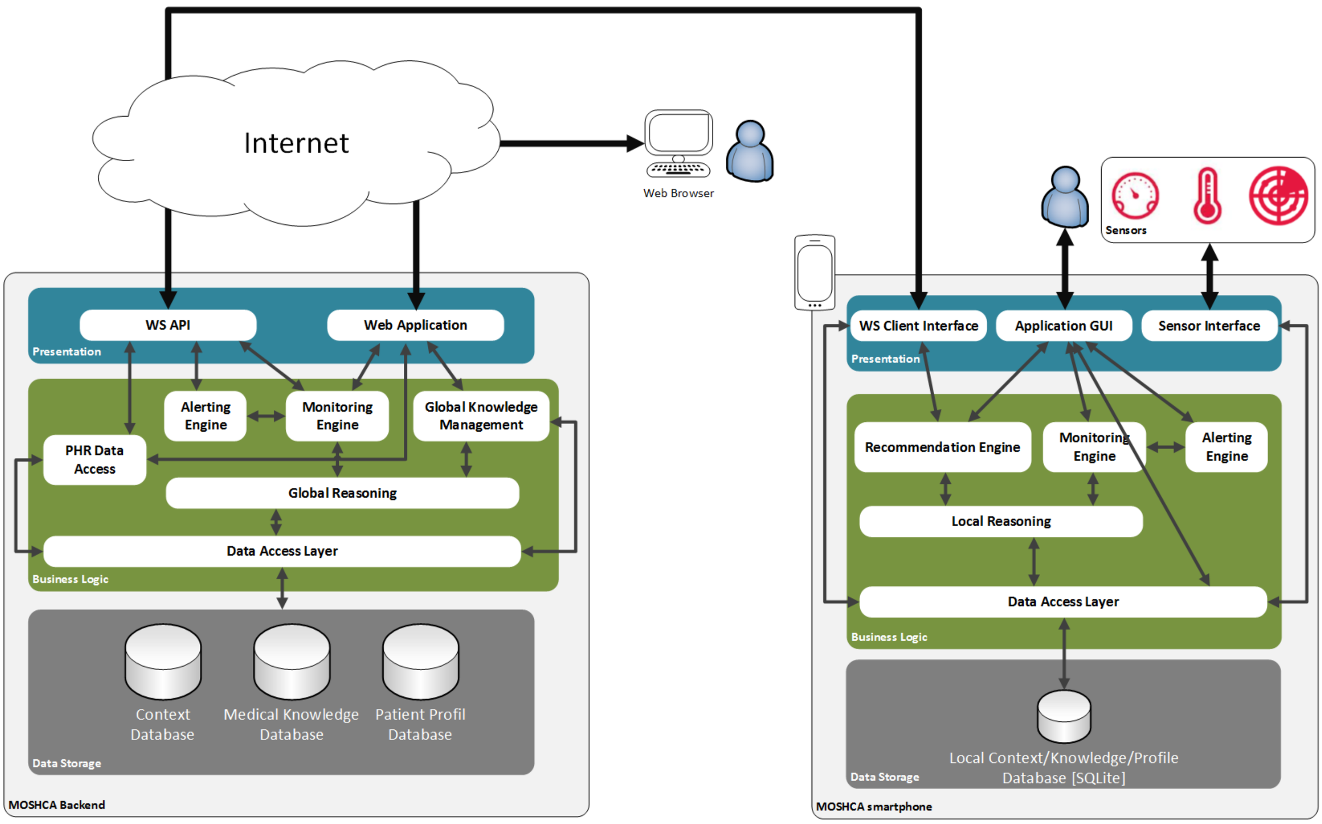

Fig. 1: Proposed architecture of a modular m-Health solution for the management of chronic disease.

back-end takes advantage of a Big Data network that allows the use of all users' data to refine the recommendations and (ii) a local simpler reasoning algorithm implemented on the smartphone. The latter can be refined by corrections calculated on the back end by the complex reasoning system and transferred during occasional synchronizing. This maintains the adaptive capabilities of the local algorithm.

Further it has been shown that automatic reminders or alerts resulting from the algorithms greatly enhance the usefulness of such m-Health solution [6]. For this reason, two alerting engines are implemented, a local one on the smartphone to directly warn the user and another one, on the back-end which can also send notifications to families, friends and doctors.

The smartphone application retrieves information from three sources of information through the Presentation interface (blue panels on Figure 1): the sources are the user, the health sensor and the back-end Web services. User view and API serve as interface. On the back-end side, more Web services API are available for the communication between the smartphone and the back-end.

The business logic component (green) is composed of several blocks. The monitoring engine which are used for real-time monitoring of the sensor data. The Recommendation and Alert engine are used to push messages and to warn the user locally on the smartphone side or to some of his carers on the back-end side. The Reasoning engines are components used to automatically derive new data or knowledge from the existing data, i.e., by interpreting the data using rules, statistical techniques or case-based reasoning. The Knowledge management describes the software component which uses and/or adapts the medical knowledge on disease. The PHR Data Access gives access to the users' medical data. To finish, the Data Access Layer handles the connection to this database and grant access to those data.

The data storage component of the SmartPhone (grey) stores the sensor's data, the user profile and some medical knowledge about the disease. When an internet connection is available the local database pushes data to the global MoSHCA database. On the back-end databases, all sensors data are stored. They comprise all users' profiles and all the medical knowledge in a secured format. This is a legal obligation in some countries to separate the patient information from the data collected. It means that the sensors' data of the Context Database are anonymous.

Finally a web application allows identified carers to access their patient's data and plot them in graphical charts. Via this website, they can also access to some services such as scheduling of new appointment or sending notifications or giving new treatment recommendations.

V. Conclusion

In conclusion, we detailed an innovative m-health system for the monitoring of chronic disease with a focus on diabetes. It extends the functionalities of the current state of the art to improve the health and comfort of diabetic patients. Furthermore, the MoSHCA application extends the usefulness of smartphone monitoring of diabetes to type 2 and gestational diabetes. It also provides wiser advice based on a wealth of information stored on the server database, in collaboration with carers.

The effort realized within the MoSHCA project should lead to the commercialization of a collection of applications using the same architecture and able to handle multiple pathologies. The flexibility and modularity of the architecture paves the way to a better and more widespread extension to other use cases by including new sensors, and adapting new databases and algorithms. The next step of this project consists in a series of user tests to estimate the patient acceptance and satisfaction [7][8].

Credit

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