Real-Time Monitoring Using Finite State-Machine Algorithms

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Abstract. This paper presents the architecture of a medical platform for chronic diseases sufferers that enables specialist physicians to have a permanent overview of the patient's health. The proposed system, HChecked, integrates the monitoring of vital parameters, reception of notification in case of any exceeding of the pre-defined limits of these parameters and prediction of the evolution of the current disease or of the possibility of occurrence of another disease. The software system follows the idea of trading systems that offers efficient prediction with a high level of security. This concept is based on a particular implementation of finite state-machine algorithms, which enable physicians to run complex rules against particular health information of a certain patient to predict the evolution of the current diseases or the appearance of others. Although the system allows many points of view, this paper is oriented towards the specific way in which complex rules are created.

Keywords: Finite state machine algorithms · e-health · Chronic diseases · Patient monitoring · Permanent watch · Medical complex rules

1 Introduction

The potential for pervasive computing is evident in almost every aspect of our lives including the hospital, emergency and critical situations, industry or education. The use of this technology in the field of health and wellness is known as pervasive health care. Mobile computing describes a new class of mobile computing devices which are becoming omnipresent in everyday life [1].

A significant proportion of the human population suffers from various medical conditions, including chronic ailments and medical emergencies due to sudden injuries. In absence of continuous medical care, many chronic ailments prove to be fatal. On the other hand, in various medical emergency scenarios, timeliness of medical attention is even more important [2]. Today, chronic diseases represent the major share of the burden of disease in Europe and are responsible for 86 % of all deaths. They affect more than 80 % of people aged over 65 and represent a major challenge for health and social systems [3].

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One of the main challenges in the management of chronic diseases is the efficient and continuous monitoring of the patient's health by the health professionals. In that sense, the patient-doctor interaction is preferred to not happen in a monthly basis scheme, but it can be continuous by using monitoring systems [4]. Although this statement may seem obvious, the continuous care they should be provided is often overlooked. The use of a history of a patient's evolution may be helpful not only for that particular individual, but also for those suffering of similar symptoms. The help they need should not come only in case of an emergency, prevention being an important factor to take into consideration when speaking about chronic disease sufferers. We propose a system that is able to record and monitor a patient's health parameters by creating and distributing notifications when the received data exceeds the limits of the complex conditions that are pre-defined by the specialist physicians.

This paper is structured as follows: Sect. 2 describes the system from the hardware and software point of view, also presenting the applications the specialist physician and patient can use. Section 3 presents the finite state machine algorithm that is used to analyze the patient's data. Section 4 gives an example of how this algorithm can be used to create complex rules for a patient.

2 System Overview

Recent advances in biomedical engineering, wireless network and computer technologies have enabled the possibility of remote patient monitoring. Based on these technologies, it is possible to improve patient care, chronic disease management, and promote lifelong health and wellbeing [5].

Data mining in the medical context can be seen very challenging from the specialist's physician point of view which does not possess technical skills to write and execute complex algorithms to analyze patient health data. Moreover, adding real-time analyzing and large data sets of medical information to the equation makes the problem seem unsolvable for the end-user.

We propose as a solution a medical platform capable to abstract the problem of real-time big data analyzing, including an interface that offers the possibility to create complex equations on patient data defined as finite state-machine algorithms.

In this section we look at the complex e-health platform, taking into consideration the way the data flow is structured. This project represented Romania in the Worldwide Final of the Imagine Cup competition 2013. This is the reason why the main software technologies used in the current system are Microsoft based.

To enable the continuous care a chronic disease patient needs, the platform offers the doctors various applications that work on different devices. The smartphone/tablet application for physician helps the doctors to be up to date with the health state of the patient and can receive notifications. The desktop application for physician produces the environment where the doctors can create complex rules. The smartphone application for patient collects medical data from the sensors and sends them forward to be analyzed (Fig. 1).

The data acquisition system that we used as a development kit contained different types of sensors (electrocardiogram, glucometer, pulse and oxygen in blood, galvanic

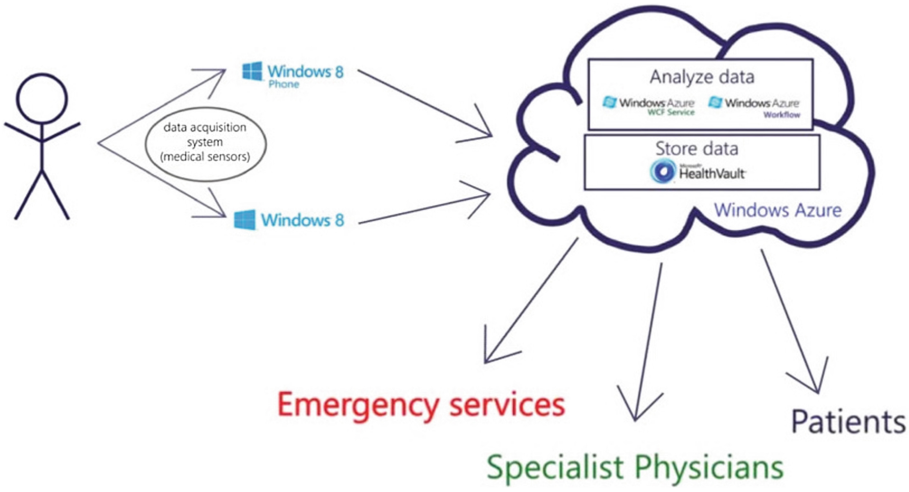

Fig. 1. Overview of the system

Fig. 2. Sensors

skin response, blood pressure, body temperature, patient position, airflow) depending on the diseases that we wished to be monitored (see Fig. 2).

From the software point of view, this system offers accurate predictions, but also a high level of security. After creating complex rules that will be described in the next section, the specialist physician will receive notifications at certain moments.

These notifications can be classified into two categories: General Notifications and Emergency Notifications. When a doctor receives a General Notification it means that the limits that he has enforced have been overcome. In such cases, the treatment should be checked or further investigations should be considered. If an Emergency Notification has been sent, physicians enrolled in the community who are in the vicinity and the ambulance are announced. For the physicians to be correctly localized, the system uses the GPS, feature that is used also for localizing the patient in need. Using these two points, the system is able to generate a map, which the doctor follows to get to the patient. When the physician reaches the patient, he is provided with a small health profile that gives him the necessary clues to know in which way he should act.

If the system were to collect all the data received from the sensors, storing them would represent a problem. However, because the limits in which we should find the health information are pre-defined, the system stores the data in the cloud only after it has been filtered.

Although the system comes in use for every individual patient in the community, the collected information, after approval and anonymization, can be also used in research projects and statistics. In this way, medical and pharmaceutical institutions can use these results for further research.

3 Analyzing Patient Data Using Finite State Machine Algorithms

We modeled the complex-rules part of the system using finite state machine algorithms because they can be easily comprehended by any specialist physician without any technical background or programming knowledge (Fig. 3).

Fig. 3. Desktop application - screenshot.

We introduce the concept of operator, which is a component of a state of the finite state-machine algorithm. Each of them can be seen as a template of simple, pre-defined equations that can be combined in any way to create a complex rule to be verified against patient data. In the first version of the system we introduce four categories of operators:

Data operators (= , < , > , ≤ , ≥). These are the simplest operators that can be used directly with the patient data. For example, the doctor can set the heart rate to be greater than 80.

Time operators (time interval, minimum period, maximum period).These operators can be used only if they are correlated with data operators. Basically, continuing the same example as above, we are able to define the heart rate to be greater than 80 for seven days (or for minimum seven days or for maximum seven days).

Number of occurrences (minimum, maximum, equal). These operators can be used with any other type, having different behavior based on the correlation that has been made. If we refer to the data operators, we verify that a patient health data respects the rule for a number of times; if we combine them with time operators we check if the occurrences happen in a certain period of time; finally if we combine them with notification operators, that will be described, there will be a number of notifications equal to the number of occurrences. It will also be included in the meta-data of the online version.

4 Use Case Example

For a better understanding of how the proposed platform can be used and how simple it is for patients to be monitored we will take a particular case of a patient suffering of both diabetes and heart disease. Diabetes by itself is now regarded as the strongest risk factor for heart disease [6]. Cardiovascular disease (CVD) is a major complication of diabetes and the leading cause of early death among people with diabetes – about 65 % of people with diabetes die from heart disease and stroke. Intensive glucose control reduces the risk of any CVD event by 42 % and the risk of heart attack, stroke, or death from CVD by 57 % [7].

Based on the data acquisition system that we currently use we will take into consideration that the patient is wearing sensors for blood glucose, heart rate and blood pressure. An example of a complex rule created by specialist physicians is presented in Fig. 4.

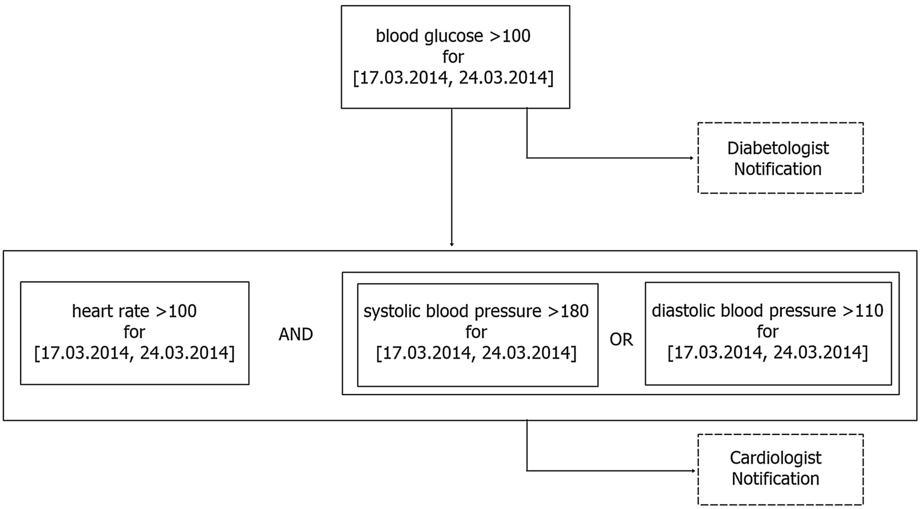

Fig. 4. Example of complex rule.

This complex rule is aimed to keep under control the blood glucose and the parameters regarding the heart disease and has two stages: first stage verifies the blood glucose of the patient for one week and the second stage checks if the heart rate and blood pressure exceed the limits pre-defined by the physician.

As seen in Fig. 4, if the patient's blood glucose is greater than 100 for one week, the diabetologist will receive a notification and then and only then the system will analyze the history data for the heart rate and blood pressure. If these parameters overcome the limits set by the cardiologist, he will be announced.

5 Conclusions

In this paper we have described an e-health platform created especially for chronic disease patients, focusing upon the way finite state machine algorithms are used to enable the physicians to create complex rules in an easy-to-use environment. While designing our system, our team consistently took into consideration the advice of medical professionals in order to identify their points of interest. The specific element of the system is the possibility to create individualized operators using basic operators, which were also previously described. This paper includes also a use case example to offer an idea about how the finite state machine algorithm is used for designing rules.

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References

1. Shahriyar, R., Faizul, M.F., Kundu, G., Ahamed, S.I., Akbar, M.M.: Intelligent mobile health monitoring system (IMHMS). Int. J. Control Autom. **2**(3), 13–28 (2009)
2. Chakravorty, R.: Mobicare: a programmable service architecture for mobile medical care. In: Proceedings of UbiCare (2006)
3. The 2014 EU Summit on Chronic Diseases, Brussels (2014). http://ec.europa.eu/health/major_chronic_diseases/docs/ev_20140403_mi_en.pdf
4. Kouris, I., Koutsouris, D.: Application of data mining techniques to efficiently monitor chronic diseases using wireless body area networks and smartphones. Univ. J. Biomed. Eng. **1** (2), 23–31 (2013)
5. Kańtoch, E., Jaworek, J., Augustyniak, P.: Design of a wearable sensor network for home monitoring system. In: Proceedings of the Federated Conference on Computer Science and Information Systems, pp. 401–403
6. Diabetes and Heart Disease — An Intimate Connection. http://www.joslin.org/info/diabetes_and_heart_disease_an_intimate_connection.html
7. The Link Between Diabetes and Cardiovascular Disease. http://www.ndep.nih.gov/media/CVD_FactSheet.pdf