A new approach to prevent cardiovascular diseases based on SCORE charts through reasoning methods and mobile monitoring

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Abstract. Nowadays, vital signs monitoring with mobile devices such as smartphones and tablets is possible through Bluetooth-enabled biometric devices. In this paper, we propose a system to monitor the risk of cardiovascular diseases in Ambient Assisted Living environments through blood pressure monitoring and other clinical factors, using mobile devices and reasoning techniques based on the Systematic Coronary Risk Evaluation Project (SCORE) charts. Mobile applications for patients and doctors, and a reasoning engine based on SWRL rules have been developed.

Keywords: Mobile Monitoring, Ambient Assisted Living, CVD Risk, Blood Pressure, Reasoning.

1 Introduction

Increasingly, the concept of Ubiquitous Computing in Healthcare environments is becoming a reality. This is explained by the advent of new embedded technologies, the wide use of universally deployed devices such as smartphones and tablets, and advances in wireless communications.

The Ambient Assisted Living (AAL) initiative[3] promotes the adoption of ICT technologies for helping elderly people, who live alone at home, to perform their daily activities, increasing their quality of life, but bearing in mind that it is crucial serving users in terms of usability. In this sense, the continuous monitoring of vital signs is essential to determine the health condition of the person at any moment, especially when the person suffers from a chronic disease or pathology which must be checked continuously. Many times, a continuous monitoring implies the use of biometric devices to obtain measures related to clinical parameters such as glucose or blood pressure among others. Also, other factors from the patient profile and/or personal medical record must be taken into account, for example: age, sex, healthy habits, measures from analytical tests

[3] http://www.aal-europe.eu/

(e.g. cholesterol level) and even social factors (e.g. the country where the person lives). All of them have a specific importance, depending on the monitoring goal.

In this paper, we will focus on blood pressure monitoring and several related factors to determine the total risk of suffering a CardioVascular Disease (CVD) for a patient. For that, we will combine a reasoning engine based on Systematic Coronary Risk Evaluation Project (SCORE) chart [1] hosted in a server with Bluetooth-mediated mobile monitoring software.

2 Related Work

In recent years, mobile technologies have been integrated in many AAL systems to improve and monitor several tasks of people who live alone at home. Nowadays, there are approaches based on mobile devices and sensors to know the health condition of the person.

In our particular domain, Villareal et al. [2] propose an architecture for diabetes monitoring by using next-generation mobile devices. Meanwhile, other projects such as the Health Buddy System project [3], connect patients in their homes with doctors to avoid hospitalization situations. In these cases, monitoring tasks are based on questionnaires, and the final results are made available to the doctor via Internet. However, these systems need a direct interaction between devices and the monitored users. On the other hand, Bluetooth specifications[4] are being integrated in standard biometric devices, facilitating many kinds of monitoring. In fact, the Continua Health Alliance[5] promotes the use of a standard datasheet or protocol to receive and manage information from Bluetooth biometric devices.

The MoMo project [4] presents a framework based on several ontological models to facilitate the development of mobile monitoring systems which integrate biometric and mobile devices. In this work, we collect monitoring data from Bluetooth biometric devices, in our case blood pressure, by means of the MoMo framework. These data are saved into the patient record.

Description logics have been employed in medical informatics for several tasks [5], such as terminology modeling (e.g. OpenGALEN [6] and SNOMED CT [7]) or decision support (e.g PRODIGY project [8]). Description logics are the base of the OWL Web Ontology Language (OWL) [9]. The OWL application areas are not only reduced to the medical field and have been applied successfully in many fields associated to Ambient Intelligence where there is a need to model data and reason upon them. In OWL, there is a trade-off between the expressivity and the reasoning time: the more expressive an ontology is, the slower the reasoning task is. Another feature of the OWL ontology is that it can be combined with SWRL rules [10], thus new knowledge about a given semantic model cannot only be generated though the built-in ontological reasoning but also through expert-defined rules. Thus, we propose the use of reasoning mechanisms taking into account OWL and SWRL features for the final CVD risk estimation.

[4] http://bluetooth.com
[5] http://www.continuaalliance.org

Nowadays, SCORE is the main method used by the European Societies of Cardiology to determine CVD risk percentage in European and Mediterranean countries. However, our proposal can be extrapolated to non-European regions turning their CVD standardized charts into SWRL rules to be used by our system depending on the specific region. For example, the Framingham Risk Score [11] is the most common method for CVD risk estimation in USA, but this is also used elsewhere in the world. All existing methods are based on clinical evidences and their results are often very similar because these have been created from a base chart score proposed for the World Health Organization (WHO) and the International Society of Hypertension (ISH) [12], but adjusted to different regions. We have chose SCORE because the system is being developed and evaluated in Spain.

3 CVD Risk Estimation Approach

The aim of our proposal is to support clinical decisions facilitating the estimation of CVD risk and related recommendations from a continuous monitoring of blood pressure at home, using the MoMo framework principles and its combination with several clinical factors from the patient record. All collected data are the inputs to the reasoning module which uses an adaptation of the MoMo ontology and a reasoning engine based on OWL and SWRL as mentioned above.

3.1 Principles and Adaptation of MoMo Framework

MoMo framework [4] allows the development of mobile applications in an adaptive, generic and remote. *Generic*, allowing the development of apps for any kind of disease. *Adaptive*, providing services adjusted to each disease depending on a patient profile. *Remote*, Medical staff is able to know all data gathered by the patient biometric devices in a non-intrusive. *Mobile*, the development of applications is based on the integration of small wireless devices.

This framework proposes the use of different patterns to design user interfaces, to specify features and to develop standardized modules, allowing the reuse of these. Also, it describes an ontological classification called *MoMOntology* providing a framework data formalization (this includes data of patient profile, diseases and recommendations among other).

In our proposal, we have used the previous principles and an adaptation of the MoMo patient profile ontology with a set of SWRL rules for CVD risk estimation.

3.2 Blood Pressure Monitoring

The European guidelines on cardiovascular disease prevention in clinical practice [1] suggest to check the blood pressure levels frequently to prevent and monitor many coronary diseases. In this sense, the number of times in one day blood pressure should be measured depends on the health condition of the person and his patient record [13].

First, we have developed an Android mobile application to get measures from a Bluetooth-powered pressure monitor, namely Stabil O GRAPH SBPM-Control[6]. These measures are stored in a remote database by means of web services. Besides, this mobile application promotes the autonomy of the monitored user because direct intervention of the physician to take new measures is not needed. In Fig. 1 is shown the sequence diagram for blood pressure monitoring.

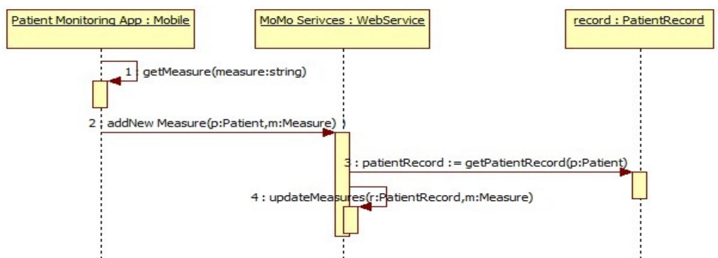

Fig. 1. Sequence diagram: A new measure of blood pressure has been taken

Most of the time, single measures do not provide sufficient information, therefore, more complex analysis are carried out. Thus, we must take into account other factors in order to make a proper assessment of risks. In the case of hypertensive people, there are 10 top high blood pressure risk factors [14]. These are: Age, Ethnicity, Gender, Family history, Smoking, Activity level, Diet, Medication and street drugs, Kidney problems, and Other medical problems. A continuous blood pressure monitoring is needed to find out hypertension problems.

3.3 CVD and SCORE Risk Charts

The analysis of blood pressure levels and other risk factors can be used to determine CVDs. In this sense, the SCORE method (see section 2), is able to estimate the 10-year risk of a first fatal atherosclerotic event, whether heart attack, stroke, aneurysm of the aorta, or other kind of CVD.Besides, SCORE charts provide a set of variables which identify the inputs to the reasoning engine. These ones are shown in Table 1 and below.

On the other hand, the outputs of the reasoning module from the previous variables have been grouped as follows.

– ***Very High***. If a user presents a risk of 15% and over.
– ***High***. If the risk is in the range 10% - 14%.
– ***Mid High***. User presents a risk from 5% to 9%.

[6] http://www.iem.de/stabil_o_graph_mobil2

Variable	Description	Type	Range
Sex	Gender of the person	Binary	Male or Female
Age	Age of the person	Discrete	[40,50,55,60,65]
Smoker	Indicates if the person smokes	Binary	True or False
Cholesterol	Cholesterol level (mmol/L)	Double	[4,5,6,7,8]
Blood Pressure	Average of Systolic Blood Pressure(mmHg)	Discrete	[120,140,160,180)
High Risk Country	Indicates if the person lives in a high risk country (view the list of the countries below)	Binary	True or False

Table 1. Input Variables

List of High Risk Countries: Countries not listed below.
List of Low Risk Countries: Andorra (AN), Austria (AU), Belgium (BE), Cyprus (CY), Denmark (DE), Finland (FI), France (FR), Germany (DE), Greece (GR), Iceland (IC), Ireland (IR), Israel (IS), Italy (IT), Luxembourg (LU), Malta (MA), Monaco (MO), The Netherlands (NL), Norway (NO), Portugal (PO), San Marino (SM), Slovenia (SL), Spain (SP), Sweden ILAR(SW), Switzerland (CH), United Kingdom (UK).

- ***Mid***. User presents a risk from 3% - 4%.
- ***Mid Low***. If the risk is 2%.
- ***Low***. If the risk presented corresponds to 1%.
- ***None***. No risk is presented.

In addition, recommendations can be offered to the physician through a specific mobile application. These recommendations can be formed from the reasoning outputs and other clinical factors (including chronic diseases such as diabetes, and other pathologies). However, our initial prototype determines the risk of CVD from the patient profile and an average of latest blood pressure measures.

3.4 Reasoning Module

The reasoning module calculates the CVD risk associated to a patient and has the ability to create patient recommendations to decrease his CVD risk. The reasoning engine uses the OWL API [15] to load the patient ontology and the SWRL rules and Pellet [16] reasoner to perform the reasoning task. SWRL rules are divided in two parts: the antecedent and the consequent. In our case, more than 250 rules have been described according to SCORE charts.

The antecedent describes the conditions which must be fulfilled to infer the consequent assumptions. In this case, the antecedents are the patient's health condition and the consequences are his CVD risk and a set of recommendation adapted to him. Final results are sent to a medical mobile application through the corresponding web services. Fig 2 shows the sequence diagram from this process, and table 2 shows an example of a complete SWRL rule according to the specific output provided by SCORE.

4 System Deployment

Our proposal consists of two Android mobile applications with which the users (patients and doctors) interact.

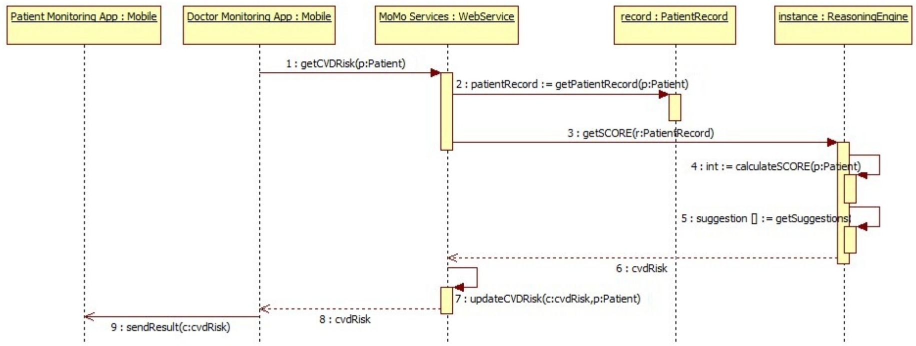

Fig. 2. Sequence diagram: CVD Risk calculation

Antecedents	
Conditions	*SWRL Translation*
Pick up an individual which is a Patient	talismanPlus:Patient(?patient) ∧
Where does she live?	talismanPlus:livesIn(?patient,?country)∧ talismanPlus:LowCVDRiskCountry(?country)∧
Is she a female?	talismanPlus:isMale(?patient,?isMale)∧ sqwrl:equal(?isMale,false)∧
How old is she?	talismanPlus:isYearsOld(?patient,?years)∧ swrlb:greaterThanOrEqual(?years,40)∧ swrlb:lessThan(?years,50)∧
Does she smoke?	talismanPlus:isSmoker(?patient,?smoke)∧ sqwrl:equal(?smoke,false)∧
Obtain her record	talismanPlus:hasRecord(?patient,?history)∧
Check her systolic blood pressure	talismanPlus:hasTest(?history,?systolic)∧ talismanPlus:SystolicBloodPressureAvgTest(?systolic)∧ talismanPlus:hasSystolicBloodPressure(?systolic,?systolicMeasure)∧ swrlb:greaterThanOrEqual(?systolicMeasure,120)∧ swrlb:lessThan(?systolicMeasure,160)∧
Check cholesterol	talismanPlus:hasTest(?history,?cholesterol)∧ talismanPlus:CholesterolTest(?cholesterol)∧ talismanPlus:hasCholesterol(?cholesterol,?cholesterolMeasure)∧ swrlb:greaterThanOrEqual(?cholesterolMeasure,4)∧ swrlb:lessThan(?cholesterolMeasure,6)
Consequent	
Action	*SWRL translation*
Set her CVD risk	→ talismanPlus:hasCVDRisk(?patient,"none")

Table 2. Example of SWRL Rule based on SCORE for a fourty-years-old non smoker woman who lives in a low CVD risk country, whose systolic blood pressure is between 120 and 160 mmHg and whose cholesterol is between 4 and 6 mmol/L.

The first mobile app allows patients to monitor their vital signs such as blood pressure as explained in this paper (see Fig. 3, step 1). Data storage and retrieval

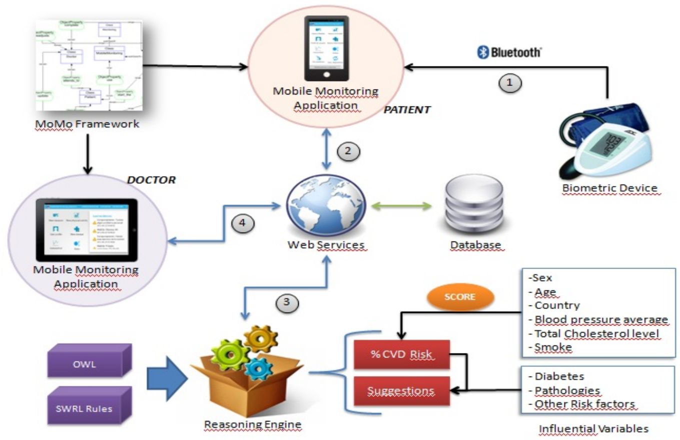

Fig. 3. System Overview

processes are carried out by transactions with web services (2). This mobile app also provides a support to receive recommendations from the doctor and create charts related to the monitored tasks. Moreover, the second mobile app allows doctors to know the health condition of patients in real time (4) by means of retrieved data from the database (including patient record) using web services. Thus, the system sends recommendations and suggestions to patients thanks to the continuous monitoring without having a direct contact with the patient and also, these suggestions may be completed and enriched by doctors.

Finally, the reasoning module developed is responsible for calculating the CVD risk and create the related recommendations taking into account the set of influential variables from the patient record. Several web services provide access to the data and the results (3).

5 Discussions and Future Work

In this work, we have presented a system to monitor the blood pressure of a patient and calculate his CVD risk applying the SCORE method.

Ongoing work is to create a set of recommendation to reduce the patient's CVD risk and deploy the system in a real AAL environment to evaluate these recommendations inferred by the reasoner. Besides, the feedback gathered will be employed to enhance the mobile user interface and to ease the human-computer interaction.

In the future, we would like to extend the application to also monitor user's dietary habits and his daily physical activity by using the accelerometer integrated into the mobile phone to check if he follows the previously issued system recommendations, thus not only monitoring his health variables but also tracking the fulfilment of the recommendations issued to prevent any coronary incident.

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