Patient-Buddy-Build: Customized Mobile Monitoring for Patients with Chronic Diseases

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***Abstract*—This work consists of developing a tool for generating mobile apps containing a questionnaire tailored to the distance monitoring of patients with chronic diseases. The customization is based on parameters and formal descriptions such as patient preferences, type of chronic disease, monitoring process required by the doctor, prescribed medication and information about the context (i.e. environment) of the patient, that are to be obtained from sensors. The questionnaire generated from this data should be completed by the patient with his/her condition and possible symptoms. These pieces of informations will be sent by the mobile app together with the data from the sensors to the responsible physician. The medical treatment and the kind of chronic disease will define the set of information to be collected. It should be stressed that the goal is not to support automatic diagnosis, but only to provide means for physicians to obtain updated information about their patients, so as to allow remote monitoring of patients.**

Keywords - mobile health; patient monitoring; ontologies; expert system; context-aware application.

I. Introduction

From the 90's until now, we can see a huge growth in the development of technologies for cellular mobile communication. The popularization of these technologies has enabled access to remote information anytime and anywhere, opening a wide range of new applications and services to users.

The number of mobile devices like smartphones grows increasingly in Brazil. According to data released by IDC, a consultancy firm specialized in technology and telecommunications market, approximately 15,4 million units of these devices have been sold in Brazil in 2012 [2].

In parallel, the coverage of mobile network also increases continuously; by the end of 2012, Brazil should have 124 million mobile broadband access points. It is expected that in the near future even low income people will have smart phones and access to mobile broadband in cities, as well as in many rural areas.

Hence, in this scenario there is an increasing urge of mobile application development for every field, including health care.

Mobile Health characterizes the practice of medicine and healthcare through mobile devices [3]. This area grows every day, and more and more hospitals and healthcare professionals are adopting to mobile technology.

The health application for mobile phones and mobile devices are expanding and changing the way of how and where medical care is done. Actively engaging patients and health professionals using sensor-rich mobile devices can help to monitor, prevent and treat diseases [4]. Furthermore, patients that have difficulties to go to a hospital or their doctors, either because they live far away or do not have sufficient funds, may benefit from a more convenient, cheaper and yet effective medical care.

This work addresses the monitoring of patients with chronic diseases mainly because of the following [1]:

- A characteristic of an aging population.
- Involves high cost treatment.
- May include high risk patients.

The remote monitoring of these patients can help to prevent their health conditions from worsening and avoid health crises. [5].

II. Objective

The main objective of this work is to develop Patient-Buddy-Build (PBB), a prototype tool for generating mobile applications containing a customized questionnaire for remote monitoring of patients with chronic diseases.

The purpose is not to develop a complete and readily usable mobile application, but to use it as a proof of concept of the proposed technique of automatic generation of mobile questionnaires from formal descriptions (including patient and doctor preferences, symptoms of disease, treatment method, etc) and to identify benefits and limitations, of the approach. In particular, this work has its focus in:

- Representation of medical knowledge and context information using ontologies [6].
- Generation of customized questionnaires using a knowledge base that contains information about the patient, available mobile sensor data, the disease and the monitoring process. The idea is that the information obtained from the questionnaires (filled out by patients) and the information provided by the sensors (such as GPS), are suitable for remote monitoring of the patient by doctors.

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The remainder of the paper is organized as follows: Section **III** describes the overall project, introduces the cooperation partners and explains what methodology is being used in this project. In Section **IV**, we describe about the current developed prototype. Section **V** gives an overview of our proposal for the final prototype and the technique of automatic generation of questionnaires for remote monitoring of patients with chronic disease. And finally, in Section **VI**, we draw some conclusions about the project.

III. Methodology

This work is being developed within the scope of the MobileHealthNet project [7], a joint effort of the Distributed Systems Lab at UFMA [8] and the Laboratory for Advanced Collaboration at PUC-Rio [9], with support from the University Hospital (HUUFMA) of UFMA (Federal university of Maranhão). In particular, the development of the Patient-Buddy-Build (PBB) is being supported by two units of the HUUFMA: The Assistance Program to Asthmatic Patients (PAPA) and the “Casa da Dor”, which specializes in treating patients suffering with chronic pain. The PBB relies on the MobileHealthNet communication middleware which has authentication and cryptographic mechanisms already implemented in it. Therefore issues regarding security will not be discussed in the paper.

The overall methodology for development of the Patient-Buddy-Build (PBB) consists of the analysis and evaluation of the results obtained from the process described below:

1. Meetings with doctors involved in the project to survey requirements regarding the monitoring of patients with chronic disease.

2. Development of a first prototype to gain more involvement with doctors, giving them a more concrete example and thus helping them to better understand how to contribute.

3. Proposal for a model with a high level language for describing processes for monitoring of patients to be discussed and refined with doctors.

IV. The First Prototype

According to number *2* (described in the previous section), a prototype was developed to give the doctors a better understanding of the tool, and to improve our familiarity with the Android platform and the communication middleware that will be used in the project. Fig. 1 shows an overview of the prototype’s components:

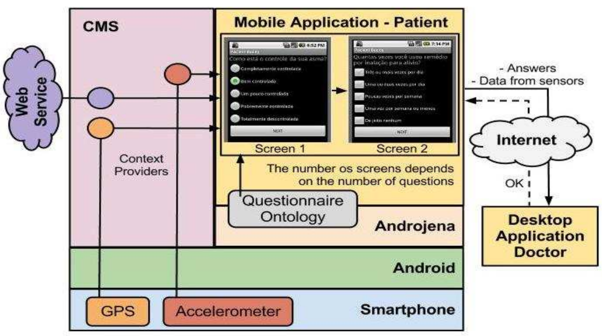

Figure 1. The first prototype.

In this first prototype a group of symptoms is associated with a questionnaire. So, depending on the symptoms that the patient has, a different questionnaire will be generated. The specialist defines the questionnaires, the group of symptoms and relates them to each other. All this information is defined through an ontology persisted in the mobile phone. This ontology defines as well how to answer each question (ex.: using a text box or preset options).

A location provider was created that informs the geographical position of the user. An address provider, that given a latitude and longitude, informs the address that the user is located. And a provider that, given an address, gathers current weather information in the region. Since we are working with chronic diseases like asthma, weather information can be very useful to better monitoring the patient.

Asthmatic patients are more susceptible to climate change. Their health condition can get worse if, for example, the weather gets too hot or too cold. For this reason was created a context provider that informs the application about the climatic conditions.

The patient executes the application and answers a questionnaire. At the end of it, the answers and the information collected by the context providers are sent to the doctor’s application that shows the information received on screen.

V. The Final Prototype

We will develop a framework for generation of mobile applications, where each one will be responsible for monitoring a patient. The monitoring will be done by collecting information from the environment and in response to questionnaires generated automatically. The idea is that these questionnaires can be answered in a quick and practical way, without excessive input text and prevalence of multiple choice answers. The information collected is sent to the doctor, so he can make an assessment of the patient’s condition. We also will develop a notification system where the doctor can, for example, notify the patient to attend the hospital for a change in treatment or further analysis.

A. The organization of the knowledge base

Here we will talk about the organization of the knowledge base [10] that will be used to generate the questionnaire and for aiding the patient monitoring. It is divided into four ontologies described below:

1) Disease Ontology: Contains disease data relevant to the application as it relates to the monitoring of patients with chronic disease. Information like symptoms, disease’s name and description.

2) Questionnaire Ontology: This ontology describes information concerning the questionnaire. Question types, e.g., font size to be used, text color, etc. The type of answer that will be allowed, for example, multiple choice, text box or by using the accelerometer provided by the smartphone.

3) Environment Ontology: Describes what context data will be captured from the environment. These data can be captured through sensors or web services. Depending on the mobile device used, it may have different sensors that can be configured to use the application. Examples: GPS (Global Positioning System), to determine location and accelerometer can be used as another way to answer questions with “yes” or “no” as possible answers. The context data will be modeled as described here [11].

4) Control Ontology: It defines the disease states in which the patient may be during monitoring. In Fig. 2 they are named as: Healthy, Pre-critic and Critic. This ontology describes how the knowledge from all the other ontologies will be applied to monitor the patient.

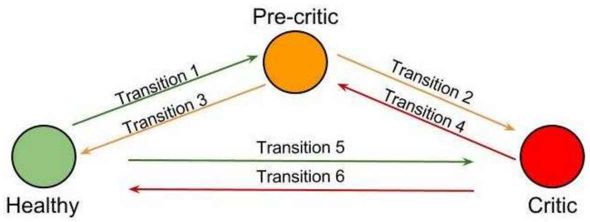

Figure 2. Control Ontology.

Each of these states has a set of rules that define whether a patient is in that state or not. Transitions have a source state and a target state; they also have a set of rules that define what is needed to go from the origin state to the target state. When a questionnaire is generated it will direct the questions to extract information to help identify if the patient’s state has changed or not.

Furthermore, this ontology also defines the frequency of the formulation of questionnaires and the factors that may trigger it. The user can set, for example that if the climate is favorable to a worsening of the patient, the frequency of the questionnaire generation should be increased.

B. An overview of the process for generating the questionnaire

Fig. 3 presents more detailed information about the transition 1, also presented in Fig. 2.

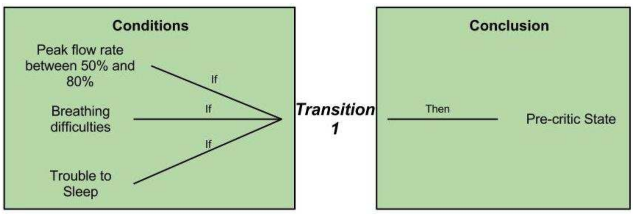

Figure 3. Transition 1.

The transitions are divided into two parts: the conditions and the conclusion. In transition 1 illustrated in fig. 3, the conditions are *breathing difficulties*, *peak flow rate between 50%-80%* and *trouble to sleep*; and the conclusion is the pre-critic state. This means that when all the conditions are true, the conclusion also will be.

The generation of the questionnaire is done while the questions are being answered by the patient. During this process, the PBB knows the last state in which the patient was classified. The first classification is given at the moment that the application is created, by the doctor.

Here is an overview of the algorithm for generating the questionnaire:

1) The program will visit each of the transitions that have the current state of the patient as the source state.

2) For each of these transitions, the program will check if the conditions are true. If they are, the patient may have his state changed.

The generation of the questionnaire is obtained through this process of verifying the conditions of the transition. For example, the transition 1 presented in Fig. 3, that has the conditions: *breathing difficulties*, *peak flow rate between 50%-80%* and *trouble to sleep*, for its verification will be raised two questions. One trying to find out if the patient has *trouble to sleep* and another asking if he has *breathing difficulties*. The verification of the condition: *peak flow rate between 50%-80%* can be done automatically through a sensor.

3) In case for all transitions, neither condition is satisfied, it is inferred that the patient is still in the same state. If all conditions of any transition are true, it is inferred that the patient is in the target state of that transition. If none of the transitions has its entire set of conditions satisfied, the program searches through the transitions with greater similarity with the patient’s acquired data and it defines the new state of the patient as being the target state of this transition. The proposed calculation of similarity will be made for each condition as follows:

- *Set A*: Set of the conditions of the transition.
- *Set B*: Set of conditions (information) acquired from the patient.
- *Result Set*: *Set A – Set B*, if Set A has a greater number of elements, or *Set B – Set A*, otherwise.

The minus sign used is the set-difference operation. The transition with the *Result Set* that has fewer elements is chosen. We now calculate the percentage of satisfied conditions that this transition has. At least 70% of the conditions of the transition should be satisfied; otherwise the state of the patient remains unchanged.

4) In this step the program now has infered a new state for the patient. It is checked all the conditions listed in the

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chosen state not yet verified with the patient. And here ends the cycle of questions.

5) The doctor will receive a report with the collected data. This report contains a brief explanation of how the diagnostic process was preformed by the application. The report will say which state (eg healthy, pre-critic or critical) the patient was in at the beginning of the questionnaire's generation. It will also tell when and why the program was seeking evidence of a possible transition to another state, aiming to indicate what steps were taken by the diagnostic process done.

It is important to understand that the goal of the process of generation of the questions is to gather information from the patient, so that the doctor can make a diagnosis and define what state the patient is. The application only suggests a state and it will not conclude anything alone. After the doctor's evaluation of the information collected by the application, he can send a notification to the patient, for example, asking him to attend the hospital.

The existence of these states aims to guide the application in the process of collecting data about the patient. They define which data the application will worry about monitoring. The application will behave according to the information described in the control ontology. Through it, the doctor can set the way he considers most appropriate to monitor his patient.

It is also possible for the doctor to disable the automatic generation of the questionnaire and manually enter a questionnaire. The rehabilitation of the generation can be made each time the doctor receives the report with the patient's data. One should note that at the time the automatic generation is turned off; all data collected through the questions have no meaning for the application and will only be persisted in text form.

VI. CONCLUSION AND FUTURE WORK

Remote monitoring enhances the contact between doctor and patient, providing them with an additional form of communication that both may decide how best to take advantage.

Several papers contained in the literature focus on monitoring patients. This work has some different approaches:

- The use of ontologies for knowledge representation.
- A proposal to separate the monitoring process of the patient from the application.
- The concept that the same system can be used for a variety of chronic disease from a change in the ontologies.
- The possibility of defining which context data will be captured from the environment.

One of the possibilities of future work is to develop new ways for the physician to insert information in the ontologies. At this stage of the work, the doctor needs a specialist in ontologies to write his or her form of monitoring their patients.

Another possibility is in the form that we represent the monitoring process dictated by the doctor. Now, it is all represented by an ontology, we could try to use first order logic, like description logic, to express the rules of the monitoring process. Using logic, the program will have much more information about the monitoring process and will have much more capability of inferring new information.

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