Towards Ubiquitous Mobile Monitoring for Health-care and Ambient Assisted Living

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Abstract

In this paper, we present a framework that enables patient mobile monitoring by using biometric devices (e.g., glucometers, blood pressure meters) to send data to a mobile phone via technologies such as WiFi, NFC or Bluetooth. An ontological architecture has been created in order to catalogue the framework elements. In addition, we provide a predictive model for managing patient history based on an analysis of past situations in order to predict future difficulties (variations in vital signs). In general, a MoMo (Mobile Monitoring) framework uses mobile phones and biometric devices to facilitate patient monitoring. Data are recorded in a central server and stored in a database to be used by the architecture.

1. Introduction

The European population is aging, as nearly 40% of the population is expected to be between the ages of 65 and 80 years old between 2010 and 2030. In order to address the economic and social challenge raised by this demographic change, the Commission proposed to launch a plan of action titled "To age well in the information society" in June, 2007.

The objective is to use the Technologies of Information and Communication (TIC) to provide a more efficient, social and sanitary assistance. The goal is also to increase opportunities for communication and innovation of auto-assistance and healthcare.

The Commission's plan of action is accompanied by a new research and development program (I+D) that intends to use TIC in order to raise the quality of life for people known as "Ambient Assisted Living". [1]

In order to improve people's lives, we are developing a mobile monitoring system that allows patients to have constant feedback regarding their vital sign tendencies as well as direct communication with their doctors. As part of our proposal, we have included a recommended diet and a prevention module. These aim to ensure a healthy lifestyle without frustrating surprises for the patients. This is our motivation for developing the framework architecture for patient monitoring via mobile phone. Mobile devices represent an important technological advance because we use them for more than 60% of our daily activities. Our MoMo (Mobile Monitoring) framework for patient monitoring is based on communication between mobile devices and biometric devices. An ontological classification has also been created for the doctor and patient modules. Classification knowledge is collected through these modules. This ontological knowledge is used by the framework to generate applications for the patient's mobile phone's and the doctor's pc.

2. Related Works

In recent years, researchers have contributed to this area because of its importance for improving people's daily lives. Mei [2] propounded the development of a framework to represent patients' vital signs. This framework facilitates the representation of the different existing standards to represent vital signs (FDA [3], CEN [3], HL7 [4], DICOM [5]). However, it only proposed a vital signs representation obtained by the mobile devices. Our proposal is not based on representation of vital signs, but rather is based on the control and interpretation of these. LATIS Pervasive Framework (LAPERF) [6] provides a framework and automatic tools for the

development and implementation of applications in pervasive computing. It is designed through a system based on rules, which filters rules not contemplated in the system.
Nirmalya [7] offers the idea of a framework supporting the merger of efficient context-aware information for healthcare applications assumed as in ambiguous context. It provides a systematic approximation to derive fragments of the context and to handle the probability of ambiguity existing in this context. In our case, we do not have ambiguity in the data. We achieve this by defining a profile for each patient, and the functionality of our architecture depends on this profile.
Broens [8] proposes the development of a framework that incorporates the use of context information. This system sends messages to different dependences associated with the framework. In an example case, a patient has symptoms of a possible epileptic seizure. Those symptoms are reported to the patient by means of an Epilepsy Safety System (ESS) called Body Area Network (BAN), which monitors the patient twenty four hours a day. The system reports to the patient who has variations of symptoms that can lead to an epileptic seizure. Our architecture facilitates patient mobile monitoring by involving the doctor, patient, and mobile phone communication. The mobile phone belongs to the patient and is the key element in their communication and self-control.
Preuveneers [9] has investigated how the mobile phone platform can help individuals diagnosed with diabetes to manage their blood glucose levels without resorting to additional systems (i.e., beyond the equipment they currently use). For example, they do not need to add any activity sensors, such as pedometers, accelerometers or heartbeat monitors, because the mobile phone is able to monitor the location and activity of the patient. Participants in this study were people diagnosed with Type-1 diabetes. We have evaluated this method of patient monitoring, and we propose that it is not necessary to record the location of the patient, but it is crucial to monitor the patient's activities. This information allowed us to learn for future situations. Our case study is Type-1 and 2 diabetes. Mamykina [10] presents a framework called MAHI (Mobile Access to Health Information), which is an application that monitors patients diagnosed with diabetes and is capable of acquiring reflexive thought skills for social interaction with diabetes educators. Our proposal involves an endocrinologist who knows the patients' specific profiles. Managing the reflexive analysis of past experiences is one of the most essential skills in controlling diabetes. MAHI is a mobile-distributed application that includes a conventional glucometer and a mobile phone that communicates with the glucometer. In contrast, Bravo [11] proposes a patient tele-monitoring process. He proposes that when using a monitoring device, a person (patient or assistant) should be able to touch a NFC (Near Field Communication) tag on the phone in order to launch the mobile phone application. Touching the NFC tag activates the monitoring device, and measurements are sent to the mobile phone through a Bluetooth connection. The mobile phone is able to make a recommendation when it obtains the measurements from the monitoring device. Incorporating such technologies may be feasible due to their low cost and low energy consumption.

3. A Patient Mobile Monitoring Framework

We have developed an architecture to provide continuous monitoring for different diseases. In figure 1, we present this architecture, which is comprised of four important elements: Mobile Monitoring Framework Structure, Layer Structure, Predictive Model and Multi-Mobile Monitoring System [12].
A. Mobile Monitoring Framework Structure: The framework initially defines a common structure for every patient´s data (ID, Name, Address, Phone Number, and others). Next, the data generated by the common structure are customized for each patient´s profile, which corresponds with each patient's measurement data (disease, doctor, and others). Secondly, the framework allows for the definition of all modules deployed by patterns (design guide), thus establishing relationships among each module and taking into account the individual profiles. With each module's definition, a relationship among them and individual profiles is possible, which enables the generation of correspondent mobiles applications. Third, the communication structure defines the protocol for device measurement, tendency management and modules.

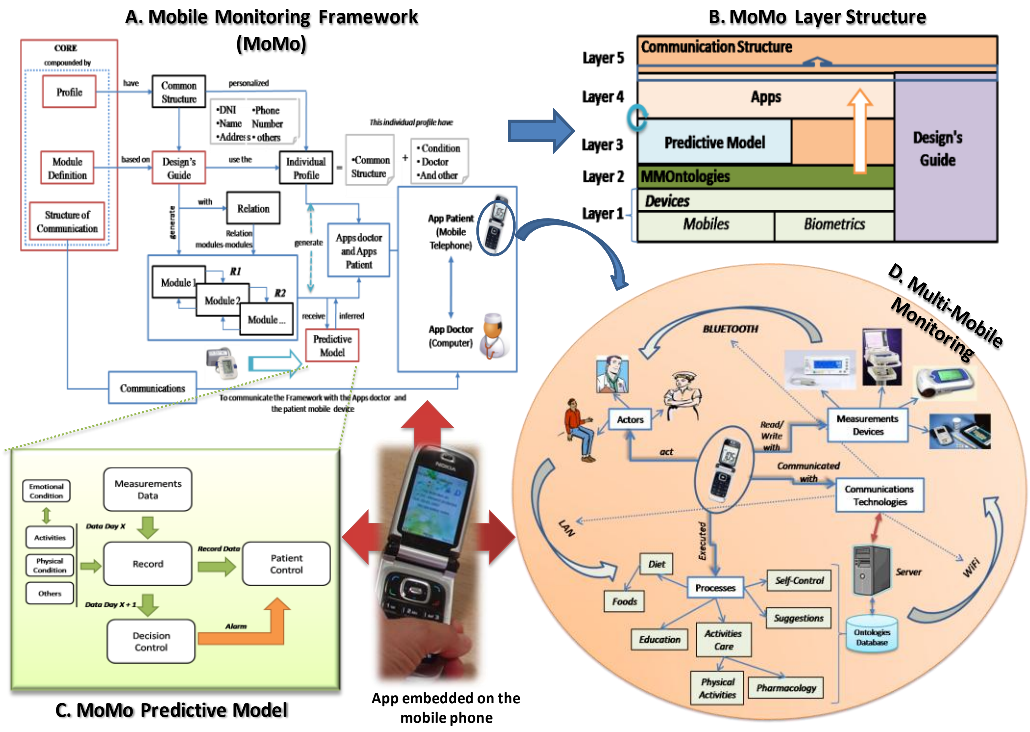

Figure 1. Mobile Monitoring Architecture with all elements

The device works by collecting data from sensors and sending it wirelessly. Next, the mobile phone automatically formalizes the received data by retrieving it in an XML document that is deployed by the framework module in a corresponding application.

B. MoMo Layer Structure: All framework elements are defined in the MoMo Layer Structure. We have placed the devices (mobiles and biometrics) in the first layer of the architecture. In the second layer, we have included the ontology defining *diseases, modules, devices, etc.*

The third layer uses a predictive model that is explained in the next section. The fourth layer includes the generation of mobile applications, and this is the most important element of the framework.

We have used a design guide for the first through fourth layers of our framework by defining different characteristics of design in these layers. Finally, the last (fifth) layer is used to define the communications structure.

C. MoMo Predictive Mode: We propose the implementation of a predictive model because the framework must be capable of generating mobile device modules for patient control according to an individual's profile and vital signs. In addition, this predictive engine will provide recommendations based on past and similar situations. We can determine, in detail, that the measurements from a specific moment (Data Day X) can be compared with stored measurements in the patient's record. The patient's record contains the activities, physical conditions, and other information from previous situations. The predictive model (Data Day X + 1) allows for patient control by sending an alarm to him/her.

D. Multi-Mobile Monitoring System: we used a server to store the information about the patient's profile, modules and ontologies. This server receives and sends data using WiFi, Bluetooth and other wireless technology.

4. Defining ontologies in the design of the framework

According to Steve´s classification [13], the proposed ontologies in the development of a framework belong to a specific domain, and this domain is intended for the mobile monitoring of patients with chronic diseases.

Our proposed architecture includes three key elements: PatientProfile, ModuleDefinition and CommunicationStructure. The PatientProfile defines each patient's data. The ModuleDefinition elements are generated according to each patient's profile, and the ComunicationStructure defines the communication between the mobile devices and the framework. For a better understanding of each of the elements in the architecture, an ontological classification of the patient´s profile is provided in addition to the ModuleDefinition. The framework uses the three key elements. The Module Definition obtains information from the Diseases and Food ontologies. The elements that comprise our application are illustrated in figure 2.

The architecture contains ontological classifications of the following elements:

PatientProfile: Defines each patient's data and is created by the CommonProfile (stores the shared information of a patient for the different diseases he or she might suffer) and the IndividualProfile (stores information associated with each of the patient's diseases).

Diseases: A range of classified diseases to which our framework can be applied. The diseases have been classified as follows: by rapidity, by frequency and by origin.

ModuleDefinition: These elements are generated according to each patient's profile. The ModuleDefinition contains the following information: Care activities, Clinical State and Medical Treatment.

Food: This ontology classifies the different types of food that a patient can consume.

These ontologies allow the framework to extract the necessary knowledge. In addition, the ontologies are interpreted by the modules to allow interoperability between each of them and the application.

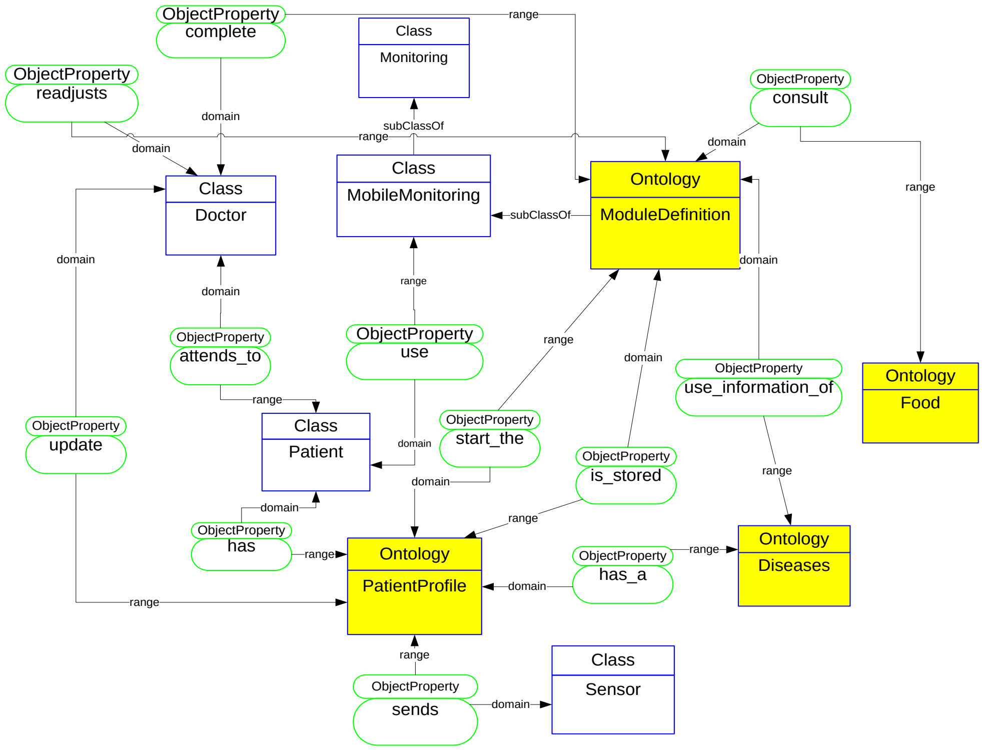

Figure 2. General ontologies diagram of patients' mobile monitoring

5. Functionality of the architecture: A case study

In figure 1, we have provided a general scheme that gives us an overview of our architecture's functionality that is based on the scheme in figure 3 but personalized for a patient who uses our architecture.

A patient visits his/her doctor (who strives to make the best decisions for every type of disease) who has an application that is generated by the framework for patient control. The information is updated in the patient's profile according to the recorded measurements and diseases that the patient may have.

After the update is finished, the framework application generates the corresponding modules of control, which are diet, recommendations, activities, alerts and education, among others. These modules are organized by the final application that is embedded on the patient's mobile phone using the following communication technology: Bluetooth, WiFi, GPS or LAN. The patient then returns to his/her daily activities while the mobile phone is in constant communication with the biometric device, which sends feedback in pre-established intervals of time. When the mobile phone detects variations in the desired levels of the patient's vital signs, it executes the corresponding modules that have been installed in this one.

In the event that important variations are detected, for example, blood sugar levels in diabetic patients, this one can activate alert signals. The doctor and patient receive a report of these variations, which allows an immediate readjustment of the modules in the mobile phone. This update can be done immediately by using a communication network or it can be addressed at the next doctor visit.

The framework stores the periodicity of these fluctuations in a prediction engine that will infer new changes to each module when visiting a doctor.

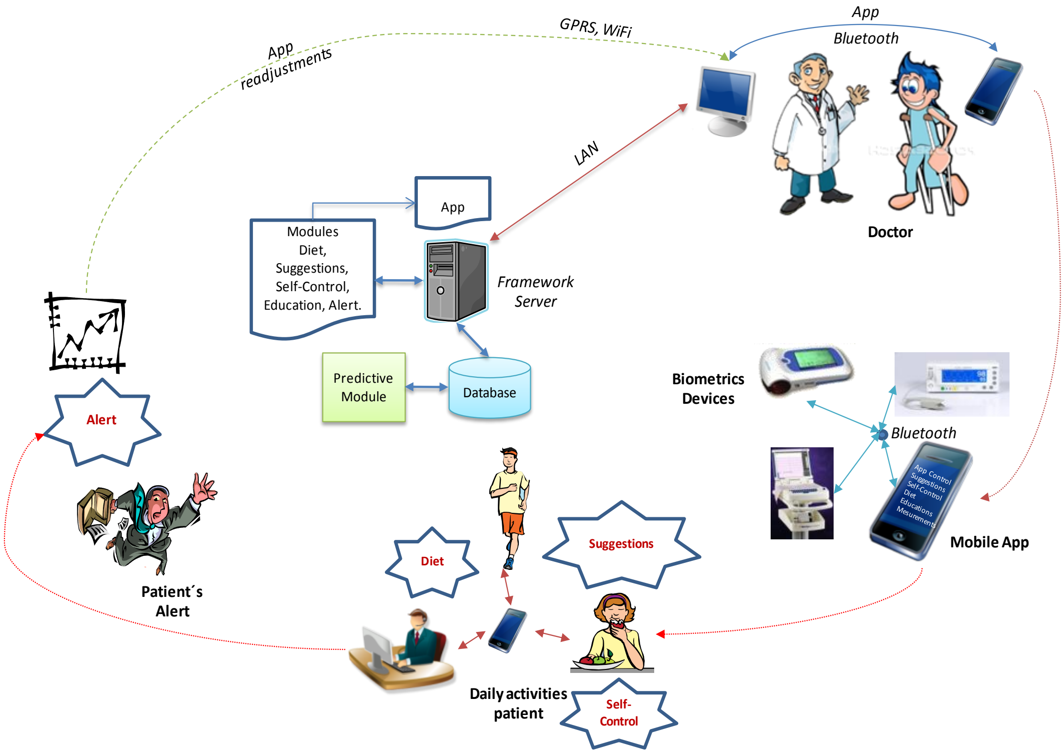

Figure 3. Functionality of the architecture with the patient and doctor

In developing our research, we classified our work in many phases associated with the software engineering method according to the advances that are reached and by relating some of these phases to other methods.
In the first phase of our research, we carried out an exhaustive study of the literature regarding patients' mobile monitoring that was based on the aspects of the development of applications, area of study and use of devices, among others.
The first phase focused on two aspects: the first one being a conceptual evaluation on theories, technologies and informative material on concepts associated with patient care, classification of diseases and use of devices; and the second aspect being the evaluation of the works developed in these fields. We were then able to identify the most important researchers in this field, the latest advances and discoveries, the important problems in this area and the limitations of the researches. We then proposed new designs and improvements.
In the second phase, we designed an architecture for patients monitoring by mobile devices. We have also proposed a layer model that allows communication through each element of the framework. The layer model allows us to develop and update this architecture. We also designed ontological classifications in the following areas: PatientProfile, Diseases, modules of control, measuring devices classification and finally the generation of applications.
Design guides allowed us to generate applications and establish the relationship between each of the elements. These design guides allow the generation of modules and applications in addition to ensuring the correct location of each element that is generated in different mobile devices (mobile phone, PDA, etc.).
In this phase, a predictive engine was defined, allowing our architecture to make decisions (always guided by the medical specialists) based on variations in vital signs and then to update the application on the mobile device. Our architecture is also able to use some technologies that allow for generating a predictive engine with future information based on past actions.
In the third phase, we developed the architecture and the visualization interface for the biometric and mobile devices.
Finally, in the fourth phase, we developed the evaluation of the framework architecture. We applied our architecture to cases that included patients with specific diseases and that also included medical specialists who were dedicated to the patient's healthcare. In this phase, we were able to evaluate the efficiency and functionality of our architecture.

6. Conclusion

Our main goal for this project is to improve the everyday life of people with chronic conditions. This paper describes the development of our framework.
This framework provides continuous patient monitoring in order to improve the communication between patients and doctors. We have generated an automatic architecture to create individual profiles for each patient, aid in self-control and provide education modules corresponding to the patient's chronic diseases.
This architecture has been developed for the mobile monitoring of patients via biometric devices and mobile phones. We have developed a framework including intervening elements with ontological classifications. Some of the aspects that are modeled in the ontologies are diet, definition, medical treatment, care activities and patient profile. These ontologies allow the framework to provide an accurate interpretation and to generate the correct applications.

References

[1] Europe's Information Society (2007). http://ec.europa.eu/information_society/newsroom/cf/itemlongdetail.cfm?item_id=3457
[2] Mei, H., et al. A Flexible Vital Sign Representation Framework for Mobile Healthcare. in Pervasive Healthcare Conference and Workshops 2006. Innsbruck, Austria.
[3] CEN. Health Informatics - Vital Signs Representation. 1999 [cited; Available from: http://www.cen.eu/cenorm/homepage.htm.
[4] HL7. Health Level Seven Standards versión 3. 2005 [cited; Available from: http://www.hl7.org.
[5] DICOM. DICOM Part 5: Data Structures and Encoding. Digital Imaging and Communications in Medicine 2004 [cited; Available from: http://www.dclunie.com/dicom-status/status.html#DiffsStandard20032004.
[6] Tadj, C. and G. Ngantchaha, Context handling in a pervasive computing system framework,

in Proceedings of the 3rd international conference on Mobile technology, applications systems. 2006, ACM: Bangkok, Thailand.
[7] Nirmalya, R., P. Gautham, and K.D. Sajal, A Middleware Framework for Ambiguous Context Mediation in Smart Healthcare Application, in Proceedings of the Third IEEE International Conference on Wireless and Mobile Computing, Networking and Communications. 2007, IEEE Computer Society: Washington, DC.
[8] Broens, T., et al., *Towards an application framework for contex-aware m-health applications.* International Journal of Internet Protocol Technology, 2007. **2**(2): p. 109-116
[9] Preuveneers, D. and Y. Berbers, Mobile phones assisting with health self-care: a diabetes case study, in Proceedings of the 10th international conference on Human computer interaction with mobile devices and services. 2008, ACM: Amsterdam, The Netherlands.
[10] Mamykina, L., E.D. Mynatt, and D.R. Kaufman, Investigating health management practices of individuals with diabetes, in Proceedings of the SIGCHI conference on Human Factors in computing systems. 2006, ACM: Montreal, Quebec, Canada.
[11] Bravo, J., et al. Enabling NFC Technology for Supporting Chronic Diseases: A Proposal for Alzheimer Caregives. in European Conference, AmI ,08. 2008. Nuremberg, Germany: Springer, LNCS.
[12] Villarreal, V., et al. A proposal for Mobile Diabetes Self-Control: Towards a Patient Monitoring Framework. in International Workshop of Ambient Assisted Living, IWAAL2009. Salamanca, Spain. LNCS.
[13] Steve, G., et al, Integrating Medical Terminologies with ONIONS Methodology, in Information Modelling and Knowledge Bases VIII (IOS). 1998, Press