MoMo: A Framework Proposal for Patient Mobile Monitoring

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ABSTRACT
In this paper, a patient mobile monitoring enabling framework is presented. To this end, biometric devices (e.g. glucometers, blood pressure meters) are used to send data to the mobile phone via technologies such as NFC or Bluetooth among others. These data are complete by the doctor for the patient control. An ontological architecture has been built up to allow the cataloguing of the framework elements. An ontological classification of the patient profile and modules definition are presented. Moreover, as study case, these ontologies are implemented for chronic diseases, based on the monitoring and control of the convalescent person. Also, we present a predictive model to allow the control of the patient history based on analysis of past situation that allow predicting situation in a certain moment (variation on vital signs). In general, MoMo (Mobile Monitoring) Framework provides a solution to patients' mobile monitoring based on mobile and biometrics devices.

Categories and Subject Descriptors
L.7.0 [**Ubiquitous/Pervasive/Mobile**]: *Wireless/Pervasive Computing*. D.3.3 [**Programming Languages**]: Language Contructs and Features – *abstract data types, polymorphism, control structures.*

General Terms
Measurement, Design, Human Factors, Languages, Theory.

Keywords
Healthcare, Ontologies, Mobile Monitoring, Ubiquitous Computing, Intelligent Systems.

1. INTRODUCTION
In order to facilitate people lives, we are working on a mobile monitoring system that allows patients to have a constant control of their vital sign tendencies as well as direct communication with their doctor. As part of our proposal we have included a diet and a prevention module; these aim to ensure a healthy lifestyle without annoying surprises for the patients. This is our motivation in developing the framework architecture for patient monitoring via mobile phone. In fact, mobile devices since it characterize the technologic advance majorly used and which we execute more than a 60% of our daily activities along. We present MoMo (Mobile Monitoring) framework for patients monitoring based on communications between mobile devices and biometric devices. A profile ontological classification has been performed as well as for the doctor´s and patient's modules. Through this classification knowledge is collected. This ontological knowledge is used by the framework for generate applications for mobile phone's patient and the doctor's pc.

2. RELATED WORK
In the last years, some researchers have contributed to this area due to the importance that has for the improvement of the way of life of the people. Mei [1] propounded the development of a framework for the representation of patients' vital signs. This framework facilitates the representation of the different existing notations to represent vital signs (FDA [2], CEN [2], HL7 [3], DICOM [4]). It'is only proposed a vital signs representation obtained by the mobile devices. Our proposal is not based on representation of vital but on the control and interpretation of these. LATIS Pervasive Framework (LAPERF) [5] provides a framework and automatic tools for the development and implementation of applications in pervasive computing. It is designed by means of a system based on rules, which filters rules not contemplated in the system. Nirmalya [6] offers the idea of a framework supporting the merger of efficient context-aware information for healthcare applications assumed as an ambiguous context. It provides a systematic approximation to derive fragments of the context and to handle the probability of ambiguity existed in this context. In our case, we do not have ambiguity in the data, to achieve this, we define an individual profile for each patient; the functionality of architecture lies on this profile. Broens [7] propounds the development of a framework which incorporates the use of context information. The system sends messages to the different dependences associated with the framework. In case a patient has symptoms of a possible epileptic seizure, by means of a Epilepsy Safety System (ESS) that includes mobile patient monitoring, Body Area Network (BAN), twenty four hours a day; the system reports to the patient who has

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variations of symptoms that can lead to an epileptic seizure. Our architecture propounds the patient mobile monitoring involving with doctor, patient, and mobile phone communication. Such mobile phone belongs to the patient and is the key element in the communication and self-control.

Preuveneers [8] has investigated how the mobile phone platform can contribute with individuals diagnosed of diabetes to handle their glucose in blood levels without resorting to no additional systems (beyond the equipment they use nowadays) or without adding any activity sensors, as pedometers, accelerometers or heartbeat monitors supervising the location and activity of the patient with the mobile phone. Participants in this study were people with Type-1 diabetes. Our proposal contemplates a patient measurements monitoring; it is not necessary to know the location of the patient, but it is crucial to know the activities the patient was carrying out then. This allows our system to learn for future situations. Our study case is Type-1 and 2 diabetes.

Mamykina [9] presents 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. In our proposal is the endocrinologist who gets involved, since he is the only one who knows the patients' specific profiles. The managing of the reflexive analysis of past experiences is one of the most essential skills in managing diabetes. MAHI is a mobile distributed application that includes a conventional glucometer, a mobile phone which communicates the mobile and glucometer. On the other hand, Bravo [10], propose a patient tele-monitoring process. He proposes that using a monitoring device, a person (patient or assistant) should be able of just touching a NFC (Near Field Communication) tag with the phone, in order to launch the mobile phone application. As a result, the monitoring device should be active and the measures sent to the mobile phone through a Bluetooth connection. When the mobile phone obtains the measures, it is in position to make a recommendation. The use of such technologies is contemplated due to the low cost and energy consumption.

3. A PATIENT MONITORING FRAMEWORK

The goal of this work is creating architecture for the generation of patients' mobile monitoring applications in any disease.

In order to improve the communication between patients and doctors, this framework provides additionally, continuous patient monitoring and supports an automatic architecture for the individual profiles of each patient, self-control and education modules for their condition. In Figure 1, we show this architecture compounded by 3 important elements: patient profile, modules definition, and the communication structure [11].

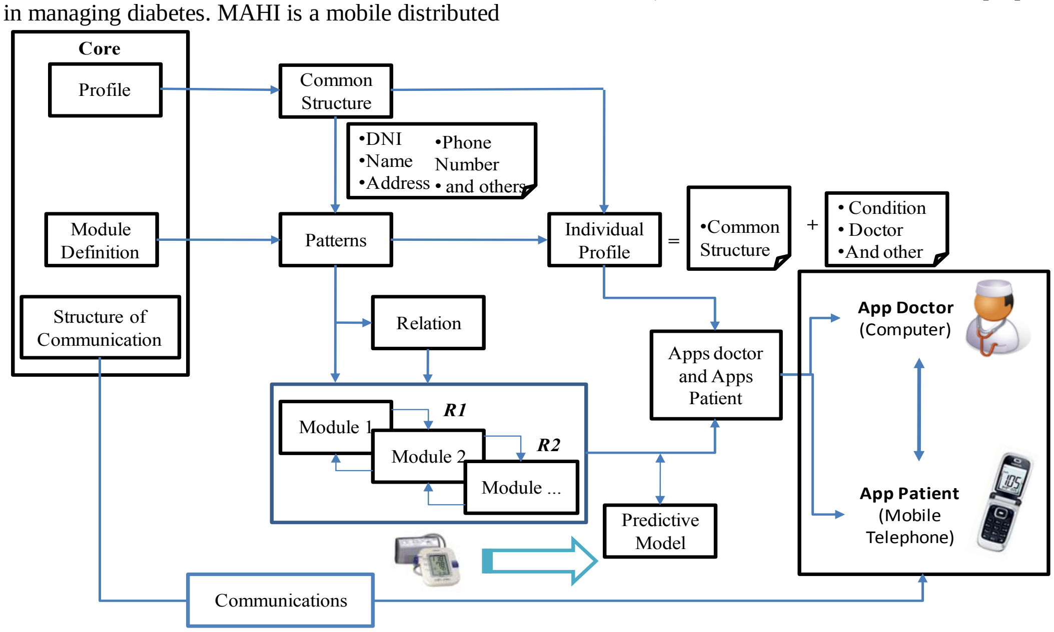

Figure 1. Framework proposal for patient mobile monitoring

First of all, the profile defines each patient's characteristics. The framework defines initially a common structure for every patient´s data (ID, Name, Address, Phone Number, and others). Next, the generated data of the common structure are customized for each patient´s profile, which can correspond with each patient's measurements data (disease, doctor, and others).

Secondly, the framework allows definition of all modules which will be deployed, via pattern definition; these patterns establish relations among each module and they are part of the required data of the individual patient profile. Modules defining patterns embed information in the individual profile of each patient. The modules definition, the relations among all of them, and the individual profile, make possible the generation of the applications for the doctor and the patient in a mobile phone.

In third place, the communication structure defines the communication protocol for the measuring devices for each kind of condition, the tendencies management and the doctor and patient modules. From a physical point of view, the device will send, via Bluetooth to the system, the data collected from its sensor. Next, the presented intermediate layer, dynamically and automatically, formalizes the received data, retrieving them in the XML document, which will be deployed by the framework module depending on its necessities. The XML document, as the intermediate layer, constitutes the initial datasheet formalization of the specific device. This common formalization of the different datasheet or specifications will enable the framework to communicate with each and every existing sensor devices and new ones to come.

4. DEFINING ONTOLOGIES IN THE DESIGN OF THE FRAMEWORK

According to Steve´s classification [12], the proposed ontologies in development of a framework belong to a specific domain; this domain is defined for the mobile monitoring of patients with chronic diseases. The proposed architecture, is formed by 3 key elements: PatientProfile, ModuleDefinition, and CommunicationStructure. PatientProfile defines each patient's data; ModuleDefinition elements generated according to each patient's profile and ComunicationStructure define a communication between 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 presented as well as of the modules definition.

This classification allows us to go into each of the functionalities that compound it in depth. In Figure 2, a classification of the initial proposed diagram is shown, viewed from an ontological perspective that demonstrates the relation among its components.

The doctor and the patient are the actors who interact with the framework. The patient has stored a profile that offers information to the framework (classified under the CommonProfile and the IndividualProfile ontologies). This individual profile allows the modules definition (MedicateTreatment, ActiveCare and ClinicalSituation ontologies). In addition, the modules definition obtains information of the Diseases and Food Ontologies. These ontological elements compose the architecture of Mobile Monitoring that will be used for the patterns and relations definition.

Attending to this classification, each of the elements that compound the definition of a determined module is related to the initial definition of the patient's profile. This generates the application´s structure for the doctor as well as for the patient, based on each of these patterns and the relations of the modules definition structure.

The elements that compound our application can be seen in figure 3 and are described below:

Monitoring: is defined at [13] as the patient's vital signs control via monitors. In interest of our application we will focus in the monitoring by means of mobile devices.

Mobile Monitoring: Defines the elements that participate in the mobile monitoring of the patients with chronic diseases. This architecture is formed by three main entities: sensor, patient and doctor. Mobile monitoring enables the follow-up and control under the doctor's supervision via the mobile phone and other communication technologies.

Doctor Entity: He or she is the person in charge of the medical activities (i.e. Treatments, diagnosis, evaluation, etc) regarding a patient.

Patient Entity: The person with the condition. Furthermore, in the architecture, he or she is the person who feeds the customised data about his/her disease.

Sensor Entity: Any device capable of fetching vital signs of a patient and sending them to the right health personnel for their appropriate interpretation. Within the propounded architecture, a biometric device can be found; this obtains the measures of some of the patient's vital signs (e.g. glucose and blood pressure, obtained via a glucometer and blood pressure meter, respectively) and a mobile phone, which catches the data (through NFC, Bluetooth, etc) and processes and interprets the values of the mentioned measures by means of an embedded application on the device.

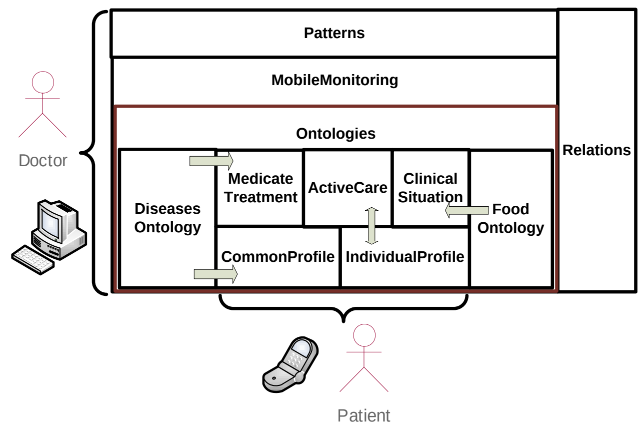

Figure. 2. Structure of the framework initial diagram with ontologies and patterns

The architecture contains the following elements' ontological classifications:

- **PatientProfile:** Defines each patient's data and it is compounded by the CommonProfile and the IndividualProfile.
- **CommonProfile**: The common profile of a patient stores the shared information of a patient for the different diseases he or she might suffer. This information is defined by his/hers personal data, where it is registered the name, address, date of birth, and sex.
- **IndividualProfile**: differing from the CommonProfile, this one has information associated with each diseases of the patient. In addition, it comprises a history where the measures and trends obtained by the sensors are stored.

Diseases: defines a classification range of diseases which our framework can be applied to. In this case, a diseases-classification-ontology has been developed following grouping criteria. They have been classified as follows:

By the rapidity they show themselves and their duration (Class "ForRapidityandDuration"): Acute, Chronic; *by the frequency they appear* (Class "ForFrecuency"): Sporadic, Endemic, or Epidemic; *by origin* (Class "ForOrigen"): Infectious, Not Infectious.

ModuleDefinition: Elements generated according to each patient's profile. It contains the following information:

Care activities (Class "ActivitiesCare"), *Clinical State* (Class "ClinicalSituation"), *Medical Treatment* (Class "MedicateTreatment").

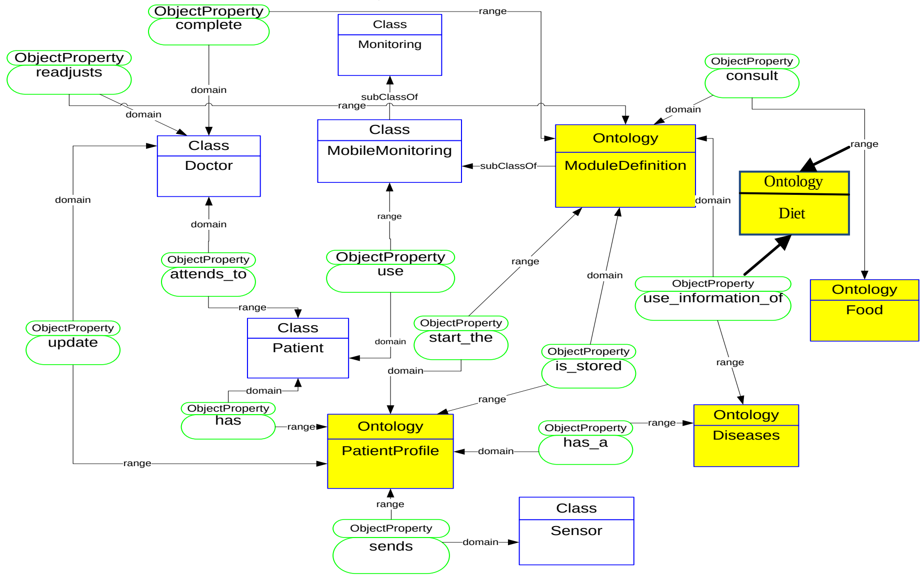

Figure. 3. General ontologies diagram for the patients' mobile monitoring

Food defines a classification of the different kinds of food a patient can consume. The ontology proposed by Cantais [14] reflects a food classification for diabetes patients, depending on their energetic content. We have added food component, the forbidden food one and the restricted food section.

5. FRAMEWORK DESIGN

Framework is based on a structure classified under the four principal phases: design, construction, execution and maintenance. Each of these phases, has a functionality defined with regard to the principal aim of the architecture. We have designed and defined the patterns that adjust to this functionality, in such a way that it allows the construction of applications for mobile devices. We have chosen to use patterns because it represents a solution arranged for the creation and development of applications, offering efficiency to the moment to implement the framework in different medical areas, allowing the adaptability of new modules of the architecture.

Table 1. Patterns definition used in the framework

Phase	Pattern	Functionality	Study case
Design	*Behaviour Pattern*	It defines the functionalities to each module.	The functionality of glycemic control module is to collect the glucose levels from the biometric device.
	Adaptability Pattern	It defines the possibility to adapt new functionalities in order that they coexist with the already existing ones.	This pattern can generate new modules with new functionalities, for example, diet adjusted the glycemic control.
Construction	*Accommodation Pattern*	It defines the location structure of each modules of the application embedded in the mobile device. It shows different functionalities in the same screen.	Glycemic control module, diets and suggestions in the same visual area.
	Visualization Pattern	It defines the visualization parameters in the device. The dimensions and functionalities have to adaptable to be visible in any device.	The same possibility of visualization in different mobile devices (mobile phone, PDA) and personal computers.
Execution	*Execution Pattern*	It defines the execution sequence of the application.	Glycemic control has to be executing on the second plane, while

			information is visualized like diets, etc.
Maintenance	*Readjustment Pattern*	It defines the structure that must adjust based on the detected changes in the execution. The application must readjust the initial values.	In case to variations in the glycemic control, the architecture can to readjusted an initially module with new suggestions, diet and treatment.

In Table 1, these elements have been classified in: phases, pattern name, a definition of functionality and presents a possible example inside. There has taken as a reference the control of a diabetic patient, since it has been first one of our cases of study. These patterns represent an initial proposes in the design of the framework, allowing the modification, deleting and creation patterns.

In the same way as patterns classification has been defined associated with every phase, in the Table 2, the distribution and functionality appears of each one of the ontologies that form part in the development of the framework. The ontology have elements that are used in some phases and that do not form a part of later phases, in addition, of the fact that exist elements of the same ontology that intervene in different phases.

Table 2. Relation between each phase and the developed ontologies

Phases	Ontologies	Ontology's Elements
Design	*Patient Profile Ontology*	CommonProfile IndividualProfile
	ModuleDefinition Ontology	ActiveCare MedicateTreatment Clinical Situation
	Diseases Ontology	ForFrecuency ForOrigin ForRapidityandDuration
Construction	*ModuleDefinition Ontology*	ActiveCare MedicateTreatment Clinical Situation
	Diet Ontology	RestrictedFood ForbiddenFood RecomendedFood
	Food Ontology	Food
Execution	*ModuleDefinition Ontology*	ActiveCare MedicateTreatment Clinical Situation
Maintenance	*PatientProfile Ontology*	IndividualProfile

6. PREDICTIVE MODEL FOR DECISIONS SUPPORT

As part of the architecture of framework, we propose the implementation of a predictive model. The framework must be capable of generating modules of control towards mobile devices for the patients, according to individual profile and the vital signs of this patient depending on the condition. In addition, being based on a clinical record and in a constant way this predictive engine will create and update, it will allow to generate recommendations based on past situations, in which there developed activities and similar stages to the presented ones nowadays. This graph can observe in detail in the figure 4.

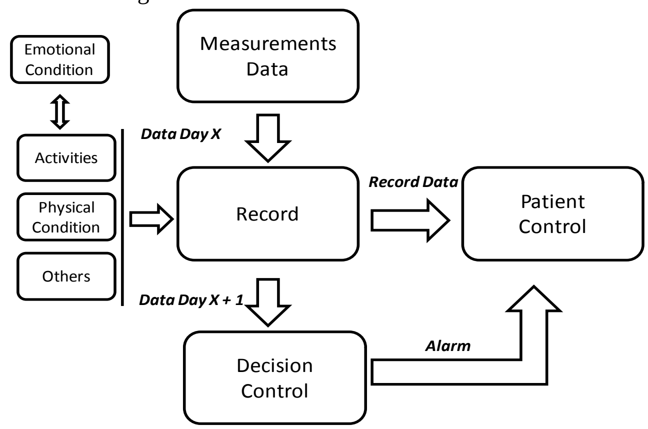

Figure 4. Relationships among the elements of the propose predictive model

The predictive model will contain situations like: activities developed that, sometimes, have altered the vital signs of the patient, record of activities, recommendations, suggestions, stored alerts in the patient individual profile, physical conditions of the patient in precise situations and exogenous aspects to the individual. This model will serve as support for capturing decisions to be used by doctors and patients. In detail, we can determinate that the measures information in a punctual moment (Data Day X) can be compared with the stored measures in the record of the patient. In addition, the record of the patient contains the activities, physical conditions and so on existing in past situations. The predictive model presents the prediction (Data Day X + 1) of possible variations before similar situations of the past, allowing the control of the patient, sending an alarm that facilitates the capture of decisions in the control of the patient. This implementation is development with neuronal networks that the control of the model.

7. CONCLUSIONS

Our main goal with this project is to promote the easy day-by-day life of people with a chronic condition. This framework will provide a continuous patient monitoring, to improve the communication between patients and doctors allowing the generation of an automatic architecture for the individual patients' profiles of each patient, self-control and education modules for their chronic diseases. This has been developed for the patients mobile monitoring via biometric devices and a mobile phone. A framework intervening elements ontological classification has been built up. These elements are the patient profile, in which the personal details of the patient are specified; and the definition of the modules for the mobile phone as well as for the doctor. Diet definition, medical treatment, care activities, patient profile are some of the aspects that have been modeled in the ontologies and that allow the framework an accurate interpretation to generate the right applications.

8. ACKNOWLEDGMENTS

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