An Ontology approach to manage individual patient profiles in home-based telemonitoring scenarios

N. Lasierra, A. Alesanco and J. García

Abstract—**This paper presents an ontology proposal to manage individual profiles for patients follow-up in home telemonitoring scenarios. It provides a formal structure with a clear semantics used as a common knowledge to exchange information among the entities involved in the telemonitoring process, thus supporting health information interoperability. Monitoring guidelines, risk situations, reminders, clinical alarms and the acquired measurements results related with physician's specifications can be gathered in the profile based on the ontology definition. To illustrate the usage of the proposed ontology to generate a patient profile, a simplified case of use associated to a patient with heart attack risk is reported as example. Finally a proposal of home telemonitoring architecture where the defined ontology can be used as a common knowledge to share information is introduced.**

I. Introduction

Home-based care of patients with chronic conditions by means of telemonitoring solutions has became widely used in last years. This shifting from the traditional way of delivering care is motivated, on the one hand by the constant increase in sanitary costs mainly due to the ageing of population in developed countries and, on the other hand, by the improvement in the quality of life these systems provide for patients.

In a home-based telemonitoring scenario, information about patients conditions (such as blood pressure measurements or just patients weight) need to be collected periodically to provide the physician with the necessary information to supervise patient's health status evolution. This telemonitoring process, and thus the required information to patient's supervision, is managed through clinical guidelines provided by physicians. Personalized guidelines must be defined for each patient in order to plan required clinical tests for patient's follow-up and their schedule, the subjective information that the patient must provide periodically about his/her health status and the actions to be taken by patients themselves or by physicians according to the acquired information. Apart from information about patient health status, additional contextual information such as patient's environment, patient's location and other characteristics about how the test was performed must be reported to accurately describe patient's context situation, in order to perform a correct diagnostic supervision. All this information involved in a home-based telemonitoring scenario i.e. monitoring guidelines, patient data results and related actions to be taken if necessary, constitutes what in this paper has been termed as patient profile. Thus, a patient profile can be seen as a container where the entire telemonitoring information for one patient's follow-up is gathered together.

Due to the heterogeneity in the information sources involved in a home-based telemonitoring scenario (patients, physicians, medical devices, etc), semantic interoperability must be guaranteed. An interesting solution to that issue would be to develop a conceptual schema with clear semantics to provide with a formal structure to define and manage individual patient profiles. This can be achieved by the use of Ontologies.

At present time, ontology definition has been emerging as a commonly used technology to represent knowledge, and its use in medical field is widely extended to define controlled medical vocabularies like SNOMED-CT [1], and also to provide a formal representation when several actors manipulate the same data. The importance to clearly represent semantics in health information is manifested in many previous researches that use medical information with different aims; see for example [2] where an ontology is developed to clearly understand concepts involved in the domain problem of a normative system for managing risk of hemodialysis patients. There are also projects that specifically define ontologies in the field of home telemonitoring. For example, in [3] a context model and a telemonitoring architecture are proposed for care delivery of people with dementia. Another example can be found in [4], where a context management middleware architecture to support health information exchange and alerts handling is proposed. The architecture is based on an ontology context model for chronic patient's monitoring.

In this paper, a new ontology model aimed to design and manage individual patient's profiles in home-based telemonitoring scenarios is defined. This ontology is used as a reference model to specify patients profile in a flexible and complete way. In contrast to other works (see [3] and [4] for example), it provides a generic framework to define patient's profile that can be used in any home telemonitoring scenario (physical diseases, psychological disorders cases or just diet supervision), thus not being restricted only to some chronic conditions. This ontology has been designated as HTPPO (Home Telemonitoring Patient Profile Ontology).

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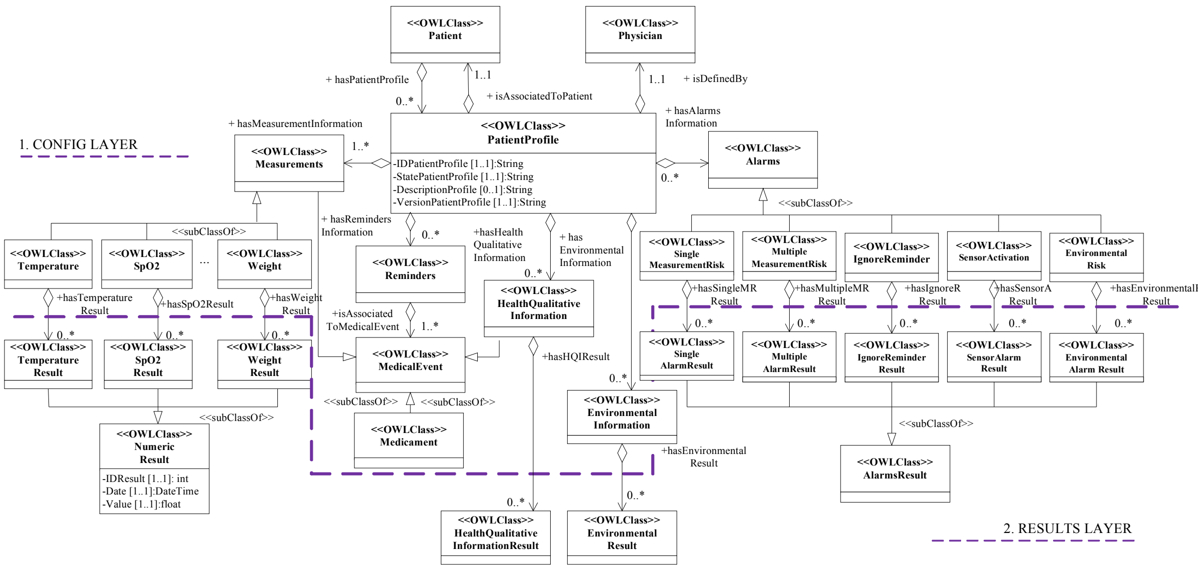

Fig. 1. Home Telemonitoring Patient Profile Ontology Representation.

II. Ontology Design

An ontology can be defined as, "an explicit and formal specification of a shared conceptualization" [5]. In practical terms, an ontology is a hierarchy of concepts with a set of properties and relations that provides a formalized representation of a common view of a determined domain. HTPPO has been developed in OWL [6], the Web Ontology Language and using the Protégé OWL editor [7] to define it. OWL describes the structure of a domain in terms of classes and properties and provides with a set of axioms to assert assumption or equivalence with respect to classes or properties. The main components of the proposed ontology are presented in Fig. 1 by means of UML (unified modeling language) class diagrams to facilitate the comprehension of the model. UML classes represent OWL classes, attributes represent OWL DataProperties and the relations between classes represent OWL ObjectProperties. Cardinality restrictions are represented as strings like 0..1 (zero or one), 1..* (one or more), 0..* (zero or more) and 1..1 (exactly one).

A. Home Telemonitoring Patient Profile Ontology Definition

The ontology model is divided into two layers. The first one, referred to as *Config Layer* (see upper part of Fig. 1), contains concepts descriptions and their relationships that refer to physician's monitoring guidelines configuration. The required measurements for patient's follow-up, data evaluation ranges (defined as alarms) or reminders configuration will be specified by the definition of instances of the classes associated to this layer. The second one, named *Results Layer* (see lower part of Fig. 1), contains the description of concepts referred to the monitoring results reported by patients, medical devices and data evaluation software modules. As can be seen in Fig. 1, concepts from *Results Layer* are linked to concepts from *Config Layer* thus all the information within the profile is related.

The class *PatientProfile*, (see Fig. 1), constitutes the core of the ontology. Each defined patient's profile will be configured as an instance of this class. One patient profile instance is generated and associated for one particular patient, but this patient could have more than one patient profile instance associated to him. A physician, whose personal data are also included in the profile, must configure the patient profile instances. All this information is represented by means of *Patient* (that includes patient's demographic data) and *Physician* class.

As it has been mentioned before, HTPPO includes all the information involved in the telemonitoring process and it is organized in five sections related to five central classes depicted in Fig. 1: Measurements, Environmental Information, Health Qualitative Information, Reminders and Alarms.

1) Measurements: a wide range of possible measurements that can be acquired in a home telemonitoring scenario have been described in the ontology in order to provide with a flexible structure to configure profiles for multiple and specific telemonitoring cases of use. All measurements concepts described in the ontology are subclasses of the *Measurements* class: weight, height, body index mass, temperature, systolic and diastolic pressure, glucose, SpO2, pulse rate, body fat, fat free mass, body water, and PEF (peak expiratory flow). Besides, quantitative information such as medicaments, foods (e.g carbohydrates, proteins, or fats) or liquids ingested by patient can be controlled by instances definition of sub-classes defined in this section although they are not provided by medical devices. Each measurement definition must be associated to a code from an international code system to correctly identify it and linked to a transmission policy in order to set some rules like frequency transmission to transfer the obtained results to the control center. For each patient, the physician will specify the required measurements to monitor patient's health condition. The acquired results associated to configured measurements will be all included in patient's profile, thus providing a means to supervise patient's health evolution.

Concepts defined in the ontology for measurement results, gather the information collected by medical devices (numeric value, acquisition date and time, and technical device information like manufacturer or model) and contextual information provided by the patient. For example, if a glucose measurement is performed to define an instance of the class *GlucoseResult* some contextual information such as when the test was performed (after or before a meal), or patient health status (stress or relax) is necessary. Additional information like the body location of the measurement performance (e.g finger or earlobe) can be also reported. In general, all issues that could directly alter the result or influence measurement result evaluation can be reported.

2) EnvironmentalInformation: variables like environmental temperature or humidity can affect patient health status so they can be reported also in the profile.

3) HealthQualitativeInformation: an instance of this class will be defined to report subjective information about patient health status (e.g stress level, mood or specific answers to personalized questions). This information is quite useful for example in patients' supervision with mental disorders or to control adverse reactions caused by a medicament when a new treatment starts. Also, information about routine activities (e.g number of lunches per day or the number of sleep hours) can be reported by instances definition of classes included in this section.

4) Reminders: this class refers to alarms targeted to patients that can be used to remind him/her the intake of a medicament, to perform a test or to update subjective information about health status. These reminders are defined by a physician and permit to schedule all the patient data retrieved from medical devices. A reminder can be periodically activated but also can be triggered by an alarm event, therefore if a unusual measurement result is detected, an associated reminder could advise the patient to take a medicament.

5) Alarms: the ontology defines five types of alarms which have some common properties like transmission policy, alarm level or notification rules. When an alarm is detected, according to the defined transmission policy, physicians or patients' relatives will be notified about it. Depending on the event that activates them, alarms are classified in: *SingleMeasurementRisk* (associated to the evaluation of a single measurement numeric result in a range and a specific context), *MultipleMeasurementRisk* (referred to the measurement results evaluation conditioned to others), *IgnoreReminder* (these alarms indicate that the medical event associated to the reminder has not to be performed), *EnvironmentalRisk* (associated to detect anomalous environmental conditions) and *SensorActivation* (fall or emergency events). Instances of the first and second alarms can be configured in the patient profile by a physician to define risk factors for the patient.

The definition of HTPPO has been a collaborative process where physicians have played an important role by determining contextual information that could influence patient's health status and that is required to accurately control them for a wide variety of telemonitoring cases. Besides, standard protocols [8] used by medical devices to communicate the acquired data have been reviewed in order to take them as a base reference to model measurements results.

B. *PatientProfile Instance Example*

Aiming to illustrate the use of the proposed ontology, an example of instance for a hypothetical patient is presented in this section. Let's assume that he is 65 years old, diabetic and smoker, and presents heart attack risk. Thus glucose, blood pressure and weight must be periodically controlled. Fig. 2 represents the instance of patient profile implemented according to the proposed ontology. Although patient profile includes configuration and results data, initially only monitoring guidelines and physicians specifications are included, and eventually, results are included on it at the time they are acquired. As it is shown in Fig. 2, systolic pressure, diastolic pressure, glucose and weight measurements are specified in the profile, hence, the related acquired results will be reported to the physician. Therefore, two reminders and three clinical alarms are also configured. Although the physician defines an initial profile, he can eventually update it according to patient evolution.

PatientProfile:5001_1	
IDProfile	"5001_1"
StatePatientProfile	"Configured"
DescriptionProfile	"Tele-monitoring profile design to patient with heart attack risk"
VersionPatientProfile	"1"
hasMeasurementInformation	SystolicPressure:5001_1_1
hasMeasurementinformation	DiastolicPressure:5001_1_1
hasMeasurementInformation	Weight:5001_1_1
hasMeasurementInformation	Glucose:5001_1_1
hasReminderInformation	Reminder:5001_1_1
hasReminderInformation	Reminder:5001_1_2
hasAlarmInformation	SingleMeasurementRisk:5001_1_1
hasAlarmsInformation	SingleMeasurementRisk:5001_1_2
hasAlarmInformation	MultipleMeasurementRisk:5001_1_1
isAssociatedToPatient	Patient:5001
isDefinedBy	Pysician:112

Fig. 2. Patient Profile Instance Representation.

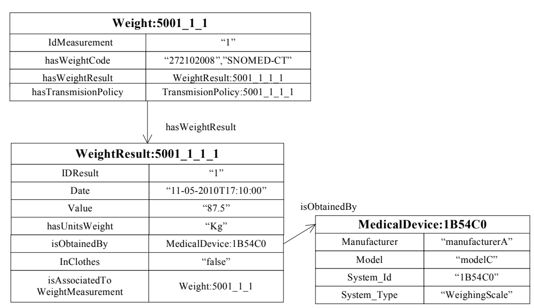

Fig.3. Weight Measurement Instance Representation.

As can be seen in Fig. 3, the acquired weight results will be associated to the weight measurement instance configuration defined by the physician ("Weight:5001_1_1") and will be reported to him according to the specified transmission policy instance "Transmision Policy: 5001_1_1_1". The weight result instance depicted in Fig. 3 reports that the patient performed a weight measurement the 11th of May of 2010 at 17:10:00 with no clothes and the weight result collected with the weighing Scale model "modelB" identified by number "1B54C0" from manufacturer "manufacturerA" was 87.5 Kg.

Finally, Fig. 4 depicts a hypertension urgent alarm instance example associated to the simultaneous evaluation of systolic pressure and diastolic pressure. It matches with the alarm "MultipleMeasurementRisk" defined in the patient profile example instance. This alarm is triggered by the third detection of a systolic pressure result over 140 mmHg and a diastolic pressure over than 90 mmHg. This alarm is notified to a designated contact person and it will be retransmitted according to the policy RP1 if after 30 minutes a confirmation value acknowledgement has not been received.

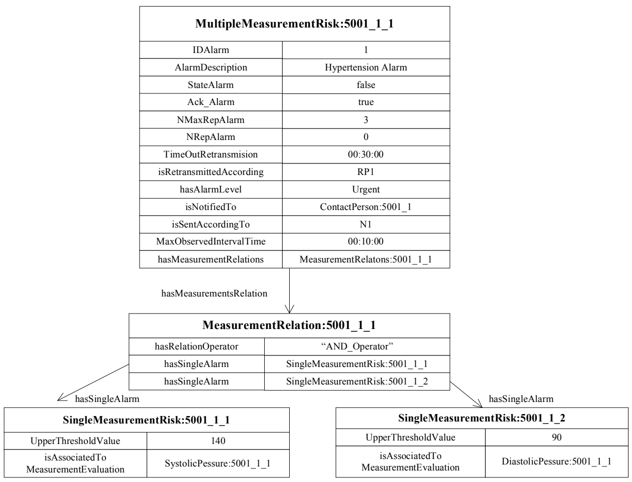

Fig. 4. Multiple Measurement Risk Alarm Instance Representation.

Other patient profile can be easily generated by simply defining the associated measurements, alarms, reminders and the relationships among them according to patient requirements.

III. HOME-BASED TELEMONITORING ARCHITECTURE

The ontology described in this paper provides a formal structure to gather and manage clinical data in a generic home-based telemonitoring system. As it is shown in Fig. 5, the ontology can be used in the conceptual layer of the architecture of our proposed home-based telemonitoring system. Clinical guidelines described by physician, results measurements obtained by medical devices and information provided by patient are related through the ontology knowledge. Thus, the ontology provides with a means to represent and transfer information from home site to the healthcare site. The physical structure is composed by the MS (Monitoring Server) which can be placed in a hospital or in a control center and several CEs (Compute Engines) associated to it. The CE is a device placed in patient's home used to gather all the medical data provided by medical devices, sensors and patients and the MS is a central server devoted to manage the information provided and collected to the CEs.

IV. CONCLUSIONS

In this paper the Home Telemonitoring Patient Profile Ontology aimed to represent knowledge in home-based telemonitoring environments is presented.

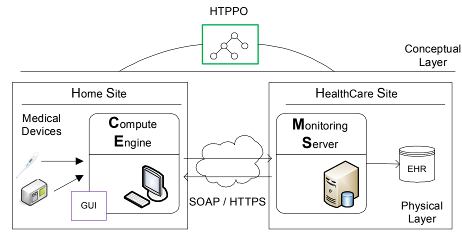

Fig. 5. General Architecture Overview.

It provides a formal structure and extensible model to define clinical guidelines, reminders, alarm situations and management and also to relate the obtained measurements results with physician's specifications. Thus, the developed ontology constitutes a generic knowledge model with a clear semantics that can be applied in any home-based telemonitoring case of use. Also, apart from monitoring guidelines description and retrieved results, it provides with a set of information to define individual management policy (transmission and evaluation data) for each defined profile.

If required, the Patient Profile ontology can be extended in order to add specific management information, particular notification policy to reminders activation regarding patient conditions and also to manage not only numeric measurements results but also waveforms results like ECG (electrocardiogram) and images results. This feature makes it a very valuable tool in telemonitoring scenarios. Currently we are working in the development of a software tool for physicians easily design patient profiles according to our ontology model.

The proposed ontology provides with a conceptual layer to be used in a general telemonitoring architecture, like the one sketched in this paper, where the information has to be exchanged among all the entities involved in the telemonitoring process.

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