# Enhancing eHealth Information Systems for chronic diseases remote monitoring systems

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***Abstract*— Statistics and demographics for the aging population in Europe are compelling. The stakes are then in terms of disability and chronic diseases whose proportions will increase because of increased life expectancy. Heart failure (HF), a serious chronic disease, induces frequent re-hospitalizations, some of which can be prevented by up-stream actions. Managing HF is quite a complex process: long, often difficult and expensive. In France, nearly one million people suffer from HF and 120,000 new cases are diagnosed every year. Managing such patients, a telemedicine system tools associated with motivation and education can significantly reduce the number of hospital days that believes therefore that the patient is hospitalized for acute HF. The current development projects are fully in prevention, human security, and remote monitoring of people in their living day-to-day spaces, from the perspective of health and wellness. These projects encompass gathering, organizing, structuring and sharing medical information. They also have to take *into account* the main *aspects* of *interoperability*. A different approach has been used to capitalize on such information: data warehouse approach, mediation approach (or integration by views) or integration approach by link (or so-called mashup).***

**In this paper, we will focus on ontologies that take a central place in the Semantic Web: on one hand, they rely on modeling from conceptual representations of the areas concerned and, on the other hand, they allow programs to make inferences over them.**

***Keywords- Ontologies; Web Semantic; Remote Monitoring; Chronic Diseases.***

## I. INTRODUCTION

The pervasiveness of chronic diseases is highly growing with increased life expectancy. In most developed countries, those diseases are responsible for increasingly growing health spending. Today, there are more than 15 million patients suffering from such diseases in France as we do expect this number to grow over 20 million by 2020 [1]. Having those patients in specialized institutions (hospitals, nursing homes ...) is not only really desired but even not possible. A European study Catalan Remote Management Evaluation (CARME) [2] has shown that there was a 68% decrease in heart failure related hospitalization and a 73% reduction of days spent in hospital from 646 days to 168 days. The move is towards solutions known as "home care", where patients are to be cared for, medically and paramedically, by remaining in their own homes. These remote monitoring solutions provide unquestionably higher quality of care and greater security than conventional practices and better quality of life for patients. They incorporate the most innovative technological aspects (monitoring and remote transmission of vital signs, detect falls, alarms, etc.) and organizational aspects necessary for the coordination of the different players contributing this “home care”. These solutions are still widely at an experimental stage, especially to assess their economic viability.

Pilot projects, with various concepts and objectives, were born throughout the world: Gator Tech [3] for the USA, Prosafe [4] for France, the work of Ogawa [5] [6] in Japan or yet CarerNet [7] for England. Most recently, we have the systems based on ontologies proposed by [8-12]. These projects vary both in scale deployment and diseases monitored (daily activities, asthma, Alzheimer's, cardiovascular disease, falls, etc.). However, they all put back up relevant information on the evolution of the patient's health including information on daily activities.

Most of these projects include various sensors to monitor the person's home (medical sensors, motion sensors, infrared sensors etc..). Some, like the Gator Tech project and the work of Tamura, focus on the instrumentation of domicile to study the lifestyle of the occupant (electronic bathroom scales, ECG in the bathtub, intelligent floors for fall detection, etc.) and make his life easier. Other projects such as TelePat [13], Ailisa [14] [15], CarerNet adjoin the sensors and home automation physiological sensors to be placed directly on the person to bring up more detailed medical data and allow a finer tracking of changes in his condition.

All this information is daily backed up to monitor patients to early detection of any abnormalities, behavioral changes or vital signs, to raise an alert. The objective of such platforms is to monitor a large number of patients. If we take the single case of heart failure patients, actually they account for France about 1 million patients with more than 120,000 new cases per year. The amount of information stored and processed is designed logically to an explosion of their volume. This has prompted the community to build integrated systems where semantics and data are coupled. The challenge in these systems is to achieve semantic interoperability.

## II. KNOWLEDGE MODELING

### *A. The main approaches*

Today, databases cover most of biomedical information: patients administrative data, clinical chemistry, clinical diagnostics, images, or even genetic data. The use of this mass of information to improve care and patient safety is still very limited. Literature offers different approaches to address some of the issues raised above, including: data warehouse approach as in BioWarehouse [16] and BioDWH [17] projects, the integration by views approach in Hemsys [18] and Tambis [19] projects or the so-called mashup in SRS [20] and Integr8 [21] projects. These different approaches offer methods and techniques to solve problems related to access to information regardless of its informative content, ie their semantics.

The increasing use of terminology, in the field of health, or ontologies in health information systems encourages the use of methodologies [22] and technologies from the Semantic Web community.

### *B. Ontologies*

Artificial intelligence has allowed knowledge to be represented in the form of a domain knowledge base and to automate their use in problem solving. These knowledge bases are generally not reusable which by the way limit their interest. To overcome this problem, the notion of ontology has been introduced [23]. An ontology is seen as a set of concepts for modeling knowledge in a given field. A concept may have several thematic senses. The concepts are linked by semantic relations, composition relations and inheritance. Many researchers have proposed definitions including:

- Guarino introduced the formal ontology notion, defined as a conceptual modeling: "An ontology is an agreement on a shared and possibly partial conceptualization" [24].

- The ontology is defined by Uschold [25] as a formal description of entities and their properties, relationships, constraints and behaviors. Furthermore, the authors introduced the notion of ontology explicit "An explicit ontology may take a variety of forms, but necessarily it will include a vocabulary of terms and some specification of their meaning".

- Thomas R. Gruber [26] which describes ontology as an explicit specification of a conceptualization of modeling concepts and relationships between concepts: "An ontology is a specification of a conceptualization. That is, an ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set-of-concept-definitions, but more general".

- John F. Sowa [27] clarified this concept and defined ontology as a type catalog from the study of categories of abstract and concrete entities that exist or may exist in a domain: "The subject of ontology is the study of the categories of things that exist or may exist in some domain. The product of such a study, called ontology, is a catalogue of the types of things that are assumed to exist in a domain of interest D from the perspective of a person who uses a language L for the purpose of talking about D. The types in the ontology represent the predicates, word senses, or concept and relation types of the language L when used to discuss topics in the domain D".

Christophe Roche [28] gave a simple and generic definition that encompasses and summarizes the above definitions "An ontology is a conceptualization of a domain to which are associated one or more vocabularies of terms. The concepts are structured into a system and participate in the meaning of terms. Ontology is defined for a particular purpose and expresses a view shared by a community. An ontology is expressed in language (representation) based on a theory (semantics) that guarantees the properties of the ontology in terms of consensus, consistency, reuse and sharing"

Ontologies are widely accepted as an appropriate form for the conceptualization of knowledge. They represent a basic step in the knowledge representation process which integrates terminology, taxonomy (organization of concepts) and description of relations among concepts and/or classes of concepts.

Using ontology enables appropriate organization of procedural knowledge and that can be beneficial for the implementation and maintenance of any complex system. Ontologies are reusable and facilitate interoperability among the application. They enable easier verification and comparison and ensure comparability of results coming from applications using the same ontology.

Ontologies can be described by meta-languages such as the Unified Modeling Language (UML), expressing the concepts in classes with attributes and operations as well as the interrelations in associations. HL7 Version 3 Normative Edition shows how to map the HL7 data types to the Object Management Group’s (OMG) Unified Modeling Language (UML) [29].

### *C. What does one represent in ontology?*

Ontologies allow representing knowledge and the way to automatically handle it, while preserving their semantics. Knowledge is defined through concepts linked together by relationships. The ontology is then presented, usually in the form of a hierarchical organization of concepts.

Concepts are represented by a set of properties and could be equivalent, not connected or dependent. They can be linked by relations defined as a connection concept between entities, often expressed by a term or a literal symbol or other. We have two types of links: hierarchical and semantic. The hierarchical relationship resumes Hyperonymy / hyponymy structuring, while the semantic relationship links the concepts through a link, said part-whole, which corresponds to the Holonymie / meronymy structuring. A hierarchical relationship links a higher member, said the hypernym element, and a lower member, said hyponym element, having the same properties as the first element with at least one additional one.

As the concepts, relationships can have algebraic properties (symmetry, reflexivity, transitivity). To describe the concepts and relationships of ontology, it is expressed in a language and is based on formalism.

#### *1) The representation formalisms*

Ontology, as described above, needs to be formally represented. Moreover, it must represent the semantic relations linking concepts. To this end, much formalism has been developed:

- The diagrams represent complex data structures. They are considered as a prototype describing a situation or standard object. They provide a benchmark for comparing objects that we wishes to recognize, analyze or classify. The prototypes must consider all possible forms of expression of knowledge. A scheme is characterized by attributes (data structure), facets (the attributes semantics) and relationships (the inheritance semantics).

- Semantic networks represent a graph structure that encodes the knowledge and their properties. The nodes of the graph represent objects (concepts, situations, events, etc..) and edges express relations between these objects. These relations can be links "kind of" expressing the inclusion relation or links "is a" showing the relationship of belonging. It includes a set of concepts describing an area completely. The interest of these graphs is their non-ambiguity and ease of use. This prompted the designers of multiple applications to use them, whether in knowledge acquisition, information retrieval and reasoning about conceptual knowledge.

- A script is a data structure that contains knowledge about a situation and which combines representations. It can be seen as a set of elementary actions or references to other scenarios, ordered according to their sequence in time.

*2) Building ontologies*

The method chosen to build ontology should be strongly guided by the desired type of ontologies and objectives of its use.There are three types of methods for the construction of ontology: manual, automatic and semi-automatic. For the first, experts create a new ontology of a domain or extend an existing ontology. In the automatic method, the ontology is built by knowledge extraction techniques: concepts and relations are extracted and then verified by the inferences. Finally, the semi-automatic, ontologies are automatically built and used to extend ontologies that was built manually.

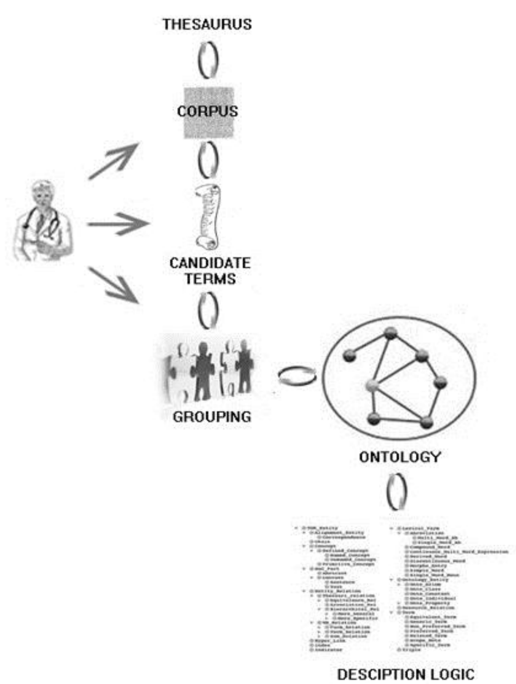


Figure 1. Steps for creating a medical ontology: *intervention at* different phases of the *ontology* development

For the medical field and chronic disease management, the creation of an ontology should go through the following steps (Figure 1):

- Establishment of a corpus of work from a thesaurus using a morpho-syntactic analysis for a list of candidate terms. A tool such as Syntex software, including working on verb phrases is particularly interesting. Furthermore, a study of the context of each candidate term would highlight additional concepts and / or to specify other relationships between concepts.

- Semantic analysis for validating candidate terms as a term of the domain by a medical expert. It would facilitate the grouping of terms validated in concepts, defining relations between concepts and between symptoms and function.

- Structuring by semantic groups.

- Finalization of the process in a language, based on description logics.

Process of designing the ontology begins after a language and a tool have been selected. There are two standard approaches to the ontology design: bottom-up approach (smaller parts of the ontology are constructed first and then later intagretaed) and top-down approach (design upper classes and the developp small pieces of the hierarchy). Though, probably the best way of creating an ontology is to combine both approaches in an iterative way.

## III. Requirements for Monitoring Patients with Chronic Diseases

The home care solutions (Figure 2) support usually innovative technological aspects (monitoring and remote transmission of vital signs, detect falls, alarms ...) and organizational aspects necessary for the coordination of different factors contributing to remain at home [30]. These solutions are still largely at an experimental stage, in order to assess the relationship between cost, reliability, the medical service and economies of scale they are likely to make to the health system overall.

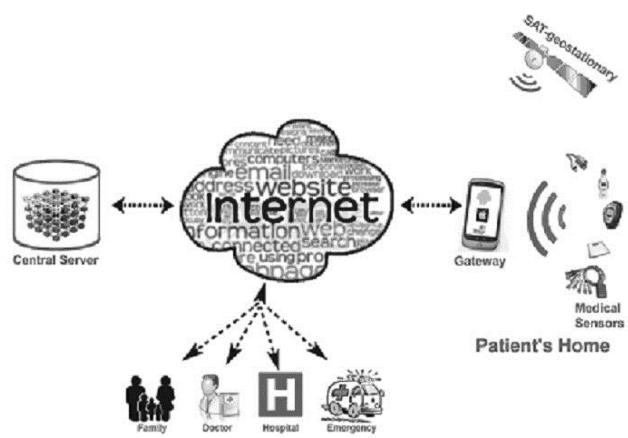


Figure 2. An evolving architecture, encompassing a full set of domestic and medical devices along with the analysis and interpretation of data

Most of these systems are designed and intended to follow a particular chronic disease (heart failure, respiratory failure, diabetes ...) and require fairly large technological equipment (sensors, computers located at home, set-top boxes for the transmission information ...). However, older people are multi-disease, with both of several chronic disorders related to age. Technically and economically it can't be considered to increase the monitoring systems number. It is therefore necessary to focus on the interoperability of these systems, so as to factor out the common elements, thereby reducing costs of deployment and operation.

Elderly patients are often multi-pathological so currently it is necessary to multiply the patient's home systems. This profusion of systems has little interest because most of them uses similar equipment to perform their measurements. Motion sensors for example are found in virtually all existing solutions.

To avoid this multiplication of equipment we must adopt architecture to pool them. Thus, even a motion sensor can be used by different applications. This pooling of equipment meets both an economic need but also a demand of patients seen in general who wish to limit the proliferation of such equipment in their homes.

In practice this mutualization and this consideration multi-phatologiques will translate by monitoring platforms necessarily evolving which can therefore integrate knowledge about various diseases. Ontologies represent then formalism well adapted to enable the integration of new knowledge and / or to make available the knowledge.

### A. The heterogeneity of medical knowledge

The information and resources used to consider and treat various diseases are necessarily heterogeneous and make their understanding and analysis very difficult. Meaning preservation of information shared is then an important problem. This is what is called semantic interoperability. A commonly accepted definition for semantic interoperability, *"it gives meaning to the information shared and ensures that this is common sense in all systems between which exchanges must be implemented"* [31-33]. Consideration of this semantics enables distributed systems to combine received information with local information and treat all consistently.

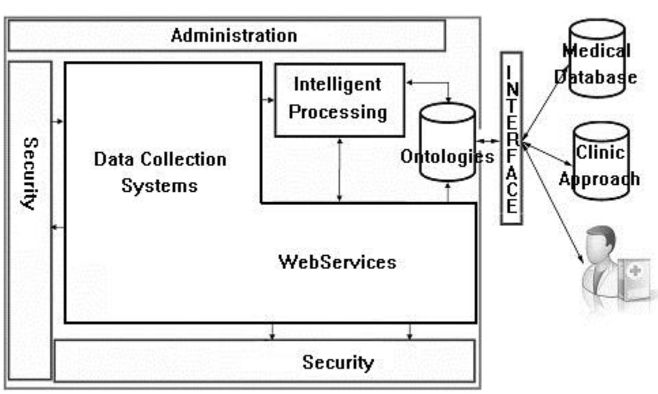


Figure 3. Ontologies are an effective way for the representation and the sharing of knowledge

To ensure semantic interoperability, information shared between systems (Figure 3) must first be described in a formal structure for preserving its semantics. This is a recurring problem in the field of knowledge engineering, where methodologies and techniques are proposed to collect, identify, analyze, organize and share knowledge between different entities. Among these techniques, ontologies are experiencing a rapid development over the ten years past and appear as an effective way for knowledge representation.

### B. Techniques for semantic interoperability.

A number of techniques have been proposed in the literature to achieve interoperability [34]. They are often used to allow data sharing between heterogeneous knowledge bases and for the re-use of these bases.

We can distinguish three main categories which are:

- The alignment of ontologies [35], for whom the goal is to find correspondences between ontologies. It is usually described as an application of the MATCH operator [65], whose input consists of a set of ontologies and output, formed correspondences between these ontologies

- The mapping of ontologies which allows, for example, to query heterogeneous knowledge bases using a common interface or transforming data between different representations.

- The merging of ontologies, which creates a new ontology, called the merged ontology with the knowledge of the original ontologies. The challenge then is to ensure that all correspondences and differences between ontologies are properly reflected in the resulting ontology.

Generally speaking, providing semantic interoperability among heterogeneous ontologies is still primarily a semi-automated process.

## IV. DISCUSSION

Ontologies are necessary to both facilitate goals semantic structuring with their relations and take into account the heterogeneity of knowledge in a growing field such as monitoring patients at home and especially patients with chronic diseases. Their increasing use in this area, leads to in significant availability of ontologies that drives us to think about when to re-use them.

It is then important to take into account both their popularity and also the simplicity of their implementation. The ratio of these two parameters allows us to gauge the interest to investigate their interoperability.

Ontology engineering and management have to encompass the entire ontology lifecycle: creation, coordination and merging [37]. Merging tools or alignment of ontologies allow the integration of information from a distributed environment or heterogeneous systems. It is essential to establish semantic correspondences between ontologies that describe this shared information.

The role of alignment tools [1] is to search for matches between the concepts of distinct ontologies, to allow the joint consideration of the resources they describe. This is to combine the techniques and methods of matching linguistic, syntactic, semantic or structural. Reference [38] enriched ontologies based on thin semantic analysis of concept of labels and in the fact that regularities exist in the way of naming them. These naming conventions are used to establish mappings between these labels and axioms of the ontology, which makes semantic information explicit and then use it to automatically reason above.

Currently there exist a variety of heuristics and other techniques that can be utilised for semantic interoperability, but there is still plenty of scope for refinement and for providing fully automated frameworks.

## V. CONCLUSION

In order to provide a consistent solution in the field of medical telemonitoring, monitoring systems must take into account different pathologies in order to avoid duplication of equipment. They must therefore be open and scalable to allow the sharing and management of heterogeneous knowledge.

Ontologies are particularly suited for understanding, sharing and integrating information. However, various problems are still open, others appear: design method ontologies, representation and reasoning on ontologies, automatic generation of ontologies, ontology alignment and development, representation and data persistence based ontological systems integration based ontological design databases accessible from ontologies, integration of blur in ontologies, etc..

Beyond the issues raised by the heterogeneity of available data, the sequence of algorithmic processes that can exploit this data represents a scientific and technical challenge.

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