A Knowledge Model Driven Solution for Web-Based Telemedicine Applications

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Abstract. Building knowledge-based telemedicine systems to deliver high quality services is still a challenge. The availability and capability of different human, communication and material resources play an important role in the telemedical task management process especially in emergency scenarios. In this paper we propose a knowledge model enabling intelligent, ubiquitous telemedicine tasks management. The objective of this model is to support the quality of telematic services delivered by web-based telemedicine applications. The methodology is based on a telemedicine tasks ontology representing the concepts and their interrelations, and on a set of rules that shall be applied by a Reasoner for decision making. This architecture design shall optimize the messages exchange among the different actors in the telemedicine systems, consequently providing more rapid and reliable telemedicine assistance.

Keywords. telemedicine, ubiquitous computing, context management, knowledge base, ontology, rules

1. Introduction

Ontologies have become a popular instrument within the knowledge engineering community for defining flexible, scalable, personalizable and open models of concepts and interrelations [1]. OWL (Ontology Web Language) has deserved much support both from the scientific community and from the World Wide World Consortium (W3C) these last years [2]. It has the capacity of supporting semantic interoperability to exchange and share knowledge between different systems in various domains and of enabling automated reasoning. The Ontology Definition Metamodel (ODM) [3], specified by the OMG (Object Management Group), enables ontology modelling through the use of UML-based tools. In the eHealth and telemedicine domains, ontologies are being used to solve semantic interoperability problems [4], and to propose context models for home healthcare monitoring [5]. However, using ontologies to support services and resources management in telemedicine applications is still an emerging research and development area. In a previous paper [6], we have presented a general ontology-based telemedicine system describing the main components architecture. In this paper we will detail the process of designing a knowledge base model for the intelligent management of the telemedicine tasks. We define a telemedicine task as a set of processes (such as use of generic and business services,
message set up and transmission) performed by the telemedicine system to provide the user with medical data and information that are relevant to his request. The aim of this method is to optimize the use of resources and the messages exchange among different actors, in order to enhance the quality of services in telemedicine applications taking into consideration the actor’s profile and the context of use. The core element of the system is a knowledge base driven by an ontology model which represents the different concepts (i.e., Actor, Resource, Telemedicine Task, …) and their interrelations. The services provided by the system may be for instance tele-expertise, tele-assistance for patient orientation and Electronic Health Record access. A typical application scenario is an emergency telemedical assistance in geographically critical or isolated areas such as high mountain resorts. According to the different contextual factors such as the patient clinical status, his social conditions and the hospitals locations, the system should set up several messages that shall be sent to one or more recipients inferred by the knowledge base, taking into account the availability, capability and heterogeneity of the different resources. These recipients could be for example a general medical center, an intensive care unit, a specialized hospital, etc.

In Section 2 we present the knowledge model that we designed to support the telemedicine tasks management and then in Section 3 we detail some aspects of the knowledge base realisation and implementation.

2. Knowledge Model Representation

The knowledge model we have designed is based on three main elements: ontologies, rules and reasoning. We briefly detail these elements in the following.

2.1. Telemedicine Tasks Ontology

An ontology includes a set of entities and logic statements that specify what each entity means and how they are related to each other. The main role of the ontology is to capture knowledge about the resources and actors in the telemedicine domain and to describe the different concepts and their interrelations. In other words, basing on this ontology, a telemedicine system shall offer solutions that are controlled according to a set of rules applied on or inferred from the knowledge represented by the ontology.

In our ontology we have defined five main entities: Actor, Resource, Location, Data, and TelemedicineTask. The Actor entity represents classes of individuals such as healthcare professional, patient, institution (healthcare organisations). An actor has the following attributes: ID, name, general domain, speciality, location, etc. The Resources are the available material and communication resources. Their properties are: type of resource, brand description, communication technology, total memory, bandwidth, quantity, etc. These concepts have been stratified in two layers as shown in the right panel of Figure 1. The first layer contains the description of the general concepts concerning the telemedicine services (such as Actor, Resource, Location, …) and the interrelations between these concepts. The second layer is the domain specialisation layer representing the different objects such as Cardiologist, Tele-expertise, … The telemedicine tasks are classified in different subclasses according to the medical domain such as (cardiology, neurology, diabetes, cancer, etc). The Data class includes subclasses like Biosignals, Images, Textual data, etc.
2.2. Rules and Reasoning

Various existing logic reasoning mechanisms can be used to deduce decisions that shall support the tasks management in telemedicine applications. In other words, employing reasoning techniques through knowledge models can provide an optimization of the messages exchange process taking into account the availability and capability of different resources types. Consequently, to achieve this process, different communications and management rules can be defined by a rule description language and applied by an inference engine. For example, in emergency telemedicine scenarios, a typical rule for patient orientation decision making could be: “if the requested service is tele-assistance for patient orientation (Service) and if the patient needs coronary angioplasty and stenting (Resource) then propose to the emergency physician (Actor) the closest hospital qualified to perform this treatment”.

Using ontologies and an appropriate Reasoner also allows to automatically infer the ontology class hierarchy and thus eases consistency checking. An additional service offered by a Reasoner is to test whether or not one class is a subclass of another class. By performing such tests on all of the classes of the telemedicine task ontology it is thus possible to infer the ontology class hierarchy. Based on the description of the necessary and sufficient conditions of the different classes, the Reasoner checks whether or not every class has at least one instance. The Reasoner then checks the conditions defined for each class to determine whether an individual satisfies the restrictions to be a member of a class. For example, for an individual X to be a member of the class Actor, it should at least operate one service and have one or more communication resources.
3. Knowledge Base Realization and Implementation

Figure 2 shows the main components of the knowledge base architecture which we have designed for supporting the management of telemedicine tasks. It contains a telemedicine tasks ontology repository, rules for tasks management and messages exchange optimization, a set of Reasoners and a query language.

To describe the ontologies we have used the OWL-DL (Description Logic) formalism. In OWL-DL, there are two main types of properties that can be defined. The first type is Object properties. For example, actor HAS resource, actor OPERATE service, service REQUIRE resource, service REQUIRE data. The second type of properties is Datatype properties. For example, HealthcareProfessional HAS speciality.

To edit the ontology we have used Protégé-OWL [7], a knowledge acquisition tool based on OWL-DL that eases the description of concepts. The left panel of Figure 1 displays a snapshot of a telemedicine task ontology represented according to OWL-DL. To test the ontology consistency and class hierarchy we have used Reasoner Racer [8].

For data retrieval from the telemedicine tasks ontology we have implemented a SPARQL [9] query language engine. SPARQL allows expressing queries across diverse data sources, whether the data are stored as RDF (Resource Description Framework) graphs or viewed as RDF via a middleware. SPARQL contains capabilities for querying required and optional graph patterns (Figure 3).

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  FILTER regex (?Connection_Technology, "HSDPA")
  OPTIONAL { ?HealthCare_Professional :IsLocatedIn ?Location } }
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Figure 3. Example of SPARQL query about available telemedical HSPDA-based communication resources
For defining the different management rules we have used SWRL (Semantic Web Rule Language) [10] which is based on a combination of the OWL-DL and OWL-Lite sublanguages of OWL (Figure 4). The rules will be interpreted and executed by the inference engine Jess (Java Expert System Shell) [11] for decisions making.

Figure 4. Examples of SWRL Rules for the Telemedicine Tasks Management support. Rule 1 requires that an actor and associated devices came from the same location, while Rule 2 allows to retrieve a specific device. The last 3 rules are used to assign priorities to the telemedicine tasks according to the actor’s profile.

4. Conclusion

Telemedicine tasks management is a complex process due to applications and scenarios specificities and diversity. To master this complexity we have designed a knowledge base model for telemedicine task management. The purpose of the knowledge base is to enable an intelligent management of the messages exchange between the different actors of the telemedicine systems. The ontology has been defined and edited by OWL-DL and implemented by means of the Protégé technology which integrates inference engine Jess and SWRL as a rules language. Class hierarchy and ontology consistency have been checked thanks to the Racer Reasoner. Preliminary results demonstrate that the proposed knowledge base model facilitates the design of complex telemedical assistance processes and the management of telemedicine messages exchange and thus should contribute to the enhancement of the quality of telemedical services.

References