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A Telemedicine System for Hostile Environments

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1. Introduction

In telemedicine, a critical issue is to provide high quality healthcare services to persons located in rural areas and also in what is called hostile environments, e.g. isolated geographic areas such as high mountains resorts. These environments are potentially dangerous and difficult to reach. Moreover, in these particular environments, several factors must be considered during the telemedicine processes, especially in emergency situations. These factors could be for instance: the profiles and skills of the Rescue Team Members (RTM) or first aid persons, the technical characteristics of the telecommunication technologies embedded in the users' terminals, the availability of human and material resources and the accessibility to both the patient location and the required resources. All these factors should be taken into account to build a high performance telemedicine system. Most emergency telemedicine scenarios related to hostile environments are different, context-dependant and complex. For this reason, it is extremely difficult to define protocols or standards that meet the user needs in such environments. In addition, the decisions that should be made to orient a person who has a health problem are usually subjective and depend on the aptitude and skills of the actors who are involved in the medical tele-assistance process. From a telemedicine system point of view, the users need to perform multiple tasks in different scenarios. The management of these tasks will depend on the availability of the logistical, material and human resources that may be owned or managed by different healthcare institutions (Nageba et al., 2009). Thus, there is an essential need to design advanced telemedicine systems that are supported by knowledge models which capture knowledge about actors, tasks, resources, and organizations.

In general, the effectiveness of the healthcare services provided by the telemedicine systems is determined by many factors. The most important ones are the quality and availability of relevant information, where and when needed. However, telemedicine scenarios are various. Some of them are well know, viz patient remote monitoring (Healy et al., 2010), but other scenarios are contextual and more complex, e.g. patient tele-assistance or orientation in hostile environments like critical geographically and isolated areas where the assistant persons present next to the patient do not have enough knowledge to take the appropriate decisions (Nageba et al., 2007). This type of scenarios requires knowledge management to support the tasks and processes of medical tele-assistance.

In this chapter, we present our new Telemedicine system, called T-TROIE, standing for Telemedicine Tasks and Resources Ontology based system for Inimical Environments, which

takes into account the previous requirements to provide the healthcare professional with efficient decision making support tools. It implements a knowledge framework based on interrelated ontologies, a rule base and an inference engine (Nageba et al., 2008). T-TROIE handles contextual situations in both simple and complex scenarios using Telemedicine knowledge management. We define a "Telemedicine Task" as a set of activities ordered in sequenced steps within a telemedicine process, e.g. tele-assistance, tele-consultation, data searching, data access, message set up and transmission, etc. It is executed by a telemedicine system to provide the healthcare actors with data that are relevant to their requests.

The chapter is organized as follows. In the next section we explore some related works in the field of telemedicine, especially ontology or knowledge based telemedicine systems, in order to highlight their drawbacks and the needs these systems do not meet. In section 3 we present the telemedicine scenario we have adopted to demonstrate the feasibility of our proposed system, as well as the telemedicine process through a sequences diagram describing the user interactions with the system. In section 4 we give an overview of the T-TROIE architecture and of its components including a communication server, a task management server and a knowledge base. We detail some aspects of the T-TROIE realization and implementation in section 5.

2. Related works

Nowadays, ontologies have emerged as a significant instrument within the knowledge engineering community for defining flexible, scalable, personalizable and open models of concepts and interrelationships (Christopoulou and Kameas, 2004). The main advantage of an ontology resides in its ability to formally represent the knowledge in a given field and to interpret the data semantics. Currently, several ontology description languages are being used to formalize knowledge models.

The Ontology Web Language OWL (OWL, 2004), which has been adopted by the World Wide Web Consortium (W3C), has the capacity of supporting semantic interoperability to exchange and share knowledge between different systems in various domains and of enabling automated reasoning. It is an expressive language based on RDF (Resource Description Framework), which has the capacity of supporting semantic interoperability to exchange and share knowledge between different systems in various domains and of enabling automated reasoning on contextual information with well defined declarative semantics. Thanks to XML and OWL, it becomes easy to align different ontologies structures. On the other hand, since XML has become very popular for data exchange and the fact that the ontology description languages RDF and OWL are based on XML, adopting OWL eases ontology model transformations in terms of data representation in different formats and makes the mapping between different ontology structures an easy process. In its turn, the Object Management Group (OMG) has specified an Ontology Definition Meta-model (OMG, 2009) which enables ontology modelling through the use of UML-based tools. Despite of the diversity of scenarios, applications and services, we can classify telemedicine systems, from a system architecture point of view, into three main categories: the peer to peer P2P systems, such as the telemedicine system developed by the ARTEMIS project (ARTEMIS 2004), the Agent-based systems, such as the SAPHIRE project (SAPHIRE 2008), and the mobile systems, such as the EPI-MEDICS project (Fayn and Rubel, 2010).

From the electronic health record (EHR) access point of view, ARTEMIS (Dogac et al., 2006) has as objective to empower the sharing of the patients EHRs belonging to different

institutions by enabling the interoperability between the different existing standards, i.e. HL7, OpenEHR, and EHRcom (EN 13606). This approach is based on ontology mapping and on web services for data exchange. Another engineering approach has been developed within the scope of the ARTEMIS project to provide the exchange of meaningful clinical information among healthcare institutes through semantic mediation (Oemig and Blobel, 2009). The proposed framework provides the mapping of a source ontology into a target ontology with the help of a mapping tool producing a mapping definition which is then used to automatically transform the source ontology message instances into target message instances (Bicer et al., 2005). Smart Telehealth Home (STH) is an ontology-based model which takes advantage of the full potential of ontologies to describe the smart home domain, in order to provide an effective base for the development, the configuration and the execution of software applications (Latfi et al., 2007). The ontologies of STH (i.e. habitat ontology, person and medical history ontology, equipment ontology, behavior ontology and decision ontology) are employed to initialize Bayesian networks used for recognizing which activity is most likely to be performed by the patient at a given time and in a given place. In addition, an ontology-based model has been proposed for monitoring and assisting patient at home (Paganelli et al., 2008). The proposed model consists of several ontologies describing patient domain, home domain, alarm management and the social context ontology. The components of the proposed ontology-based model have been implemented by adopting standard technologies, i.e. internet protocols, XML and Web Services.

For areas that cannot be handled by existing telemedicine solutions, an approach has been proposed for creating scalable telemedicine networks based on Delay Tolerant Networking (DTN) using store-and-forward Voice-Over-IP (VoIP) (Scholl et al., 2009). DTN operates by leveraging mobility and local communications between participants in the network. Each member of the network communicates with other members when possible, for example when they are close enough for local wireless communications (using WiFi, Bluetooth, etc.), or when a long range link becomes available. Members store messages from each other and forward them later on when they establish connectivity with other members. This type of telemedicine network allows communication of non time-critical information between participants. However, in emergency scenarios where time is a critical factor, store-and-forward using VoIP is not an efficient solution. Additionally, a system for remote patient disease diagnosis and treatment has been proposed by Din (Din, 2010). It uses real time protocols, i.e. MPEG4/H.26X, for video and audio sessions and for connecting sophisticated medical equipments. Additionally, a High Definition TeleMedicine system (HDTM) architecture has been defined by Lu (Lu et al., 2010) that leverages the network as an intelligent transport and services platform that supports high-definition videoconferencing and audio telemetry.

The models and systems cited above present solutions based on the data captured by distributed sensors in pervasive environments, using common scenarios and standardized protocols. But, these research works neglect telemedicine scenarios problematics related to the availability and capability of heterogeneous resources in hostile environments where there are no sensors or pre-defined protocols to exchange data. Additionally, the works presented above ignore the need of knowledge management in order to provide the actors who lack the knowledge required to take the appropriate decisions, with efficient decision making support tools. In T-TROIE we have considered all the above issues to provide a more general and knowledge-based solution taking into account the specificities and diversities of contextual situations as well as the availability of the resources required to perform the telemedicine processes in hostile environments.

3. Patient orientation scenario in hostile environments

Figure 1 displays typical examples of telemedicine scenarios in different environments including home, hospitals, doctor's offices and other environments such as refuges in high mountains. The regulation center, hosting the T-TROIE system, constitutes a central point coordinating the communication among these environments. Let us take for illustration purpose a telemedicine scenario which concerns patient orientation in hostile environment such as high mountains resorts where telemedicine infrastructures and resources may be not available.

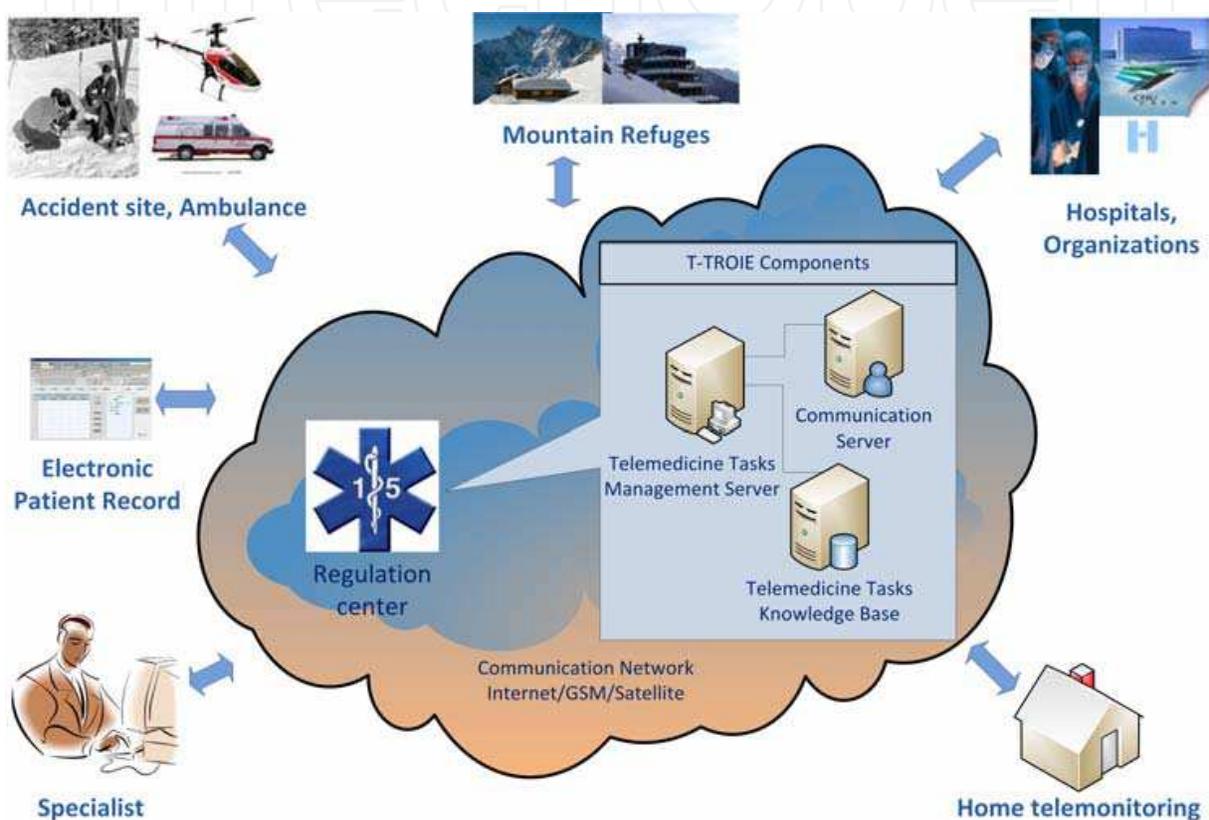


Fig. 1. Telemedicine applications scenarios in different environments

Let us suppose that a person has an accident or a heart attack while skiing or staying in a high mountains resort. The RTM or the person present next to the victim and/or the staff of the regulation center need to take a decision upon the patient orientation. This decision should consider several contextual factors such as the patient's clinical status, his social conditions, the hospital location, the availability and capability of different resources.

Using a telecommunication terminal, i.e. a Personal Digital Assistant (PDA) or a Smartphone, the RTM can connect to the T-TROIE system to perform the Patient Orientation telemedicine task. He or she should fill and submit a task form including patient personal information, e.g. first name, surname, security social number, the clinical status of the patient, e.g. heart attack, chest pain, high blood pressure, as well as the task parameters, such as, accident date, time and location.

To handle the contextual situation mentioned above, a telemedicine task, "Patient Orientation", has been defined to allow a healthcare professional or a RTM to take a decision for the transfer of the patient into an appropriate hospital that complies with the

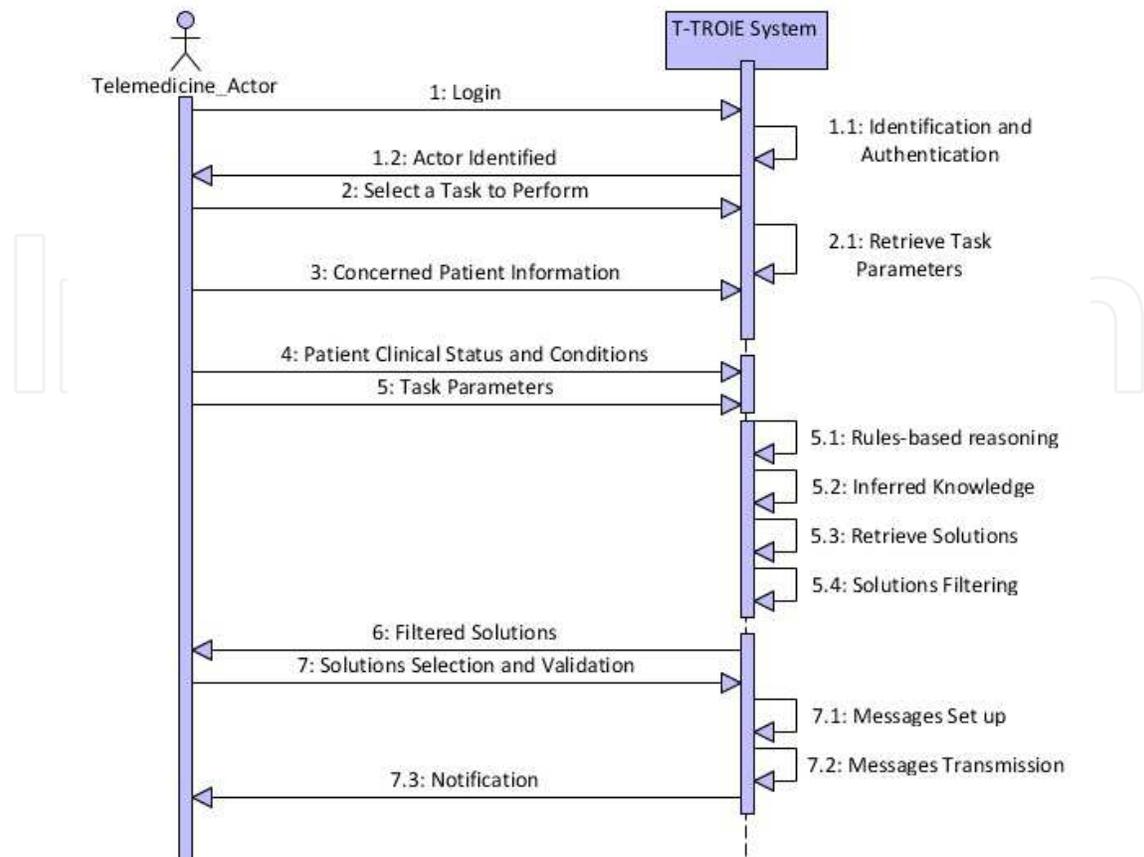


Fig. 2. Interaction diagram for a typical patient orientation scenario

patient contextual situation. We suppose that the patient has a heart attack. Depending on the clinical status of the patient, his context and the geographic location, T-TROIE will perform a rule-based reasoning and infer that the patient orientation task requires logistical resources such as an available bed in an intensive care unit and the material resources needed to perform some particular procedures like an angiography. T-TROIE will propose to the RTM a list of recipients including a general medical centre, an intensive care unit or a specialized hospital that have these resources available. Once the RTM has selected the solution that meets the context of the victim, T-TROIE will generate a set of messages that will be sent to the concerned recipient, i.e. an hospital. Then, T-TROIE will acknowledge the RTM that the selected hospital is ready to receive the patient. Figure 2 shows a sequence diagram representing the actor/system interactions and the exchanged messages.

The messages exchanged by the system are encapsulated in an XML format. The messages may be informative, for example to ask the intensive care unit to be ready to receive the patient, or provide a request for an advice, for immediate drug administration for instance, which requires a rapid response. The XML messages can include different types of data (i.e., patient's personal data, medical data such as blood pressure, symptoms descriptions, bio-signals like an ECG, and eventually a list of drugs or a digital picture of a wound).

4. T-TROIE architecture overview

Figure 3 displays the main components of the T-TROIE knowledge-based technical architecture to support the management and execution of context-dependent telemedicine

tasks and processes taking into consideration the availability and capability of heterogeneous resources needed by the telemedicine processes. The architecture is composed of three main components: a Communication server, a Task Management server and a Knowledge Base.

4.1 The communication server

The communication server manages operations such as identification, authentication, and messaging. It operates as a mediator allowing users to manage their profile and access to data. The communication server also performs the exchange of the XML messages issued by the Task Management Server by taking into account the Message Transmission Policy (MTP) that we have defined. Based on the MTP, the communication server performs the following three major processes:

- Prioritize the messages coming from the Task Management Server according to the sender and receiver actors' profiles. For example, according to the MTP, the messages sent by an emergency physician must be assigned to a high priority.
- Stratify the messages in queues according to their priorities, i.e. a high priority message queue, a medium priority messages queue and a low priority messages queue.
- Apply message transmission rules, such as, "send the first message in the high priority message queue; if there is no message in the high priority queue, send the first message in the medium priority message queue".

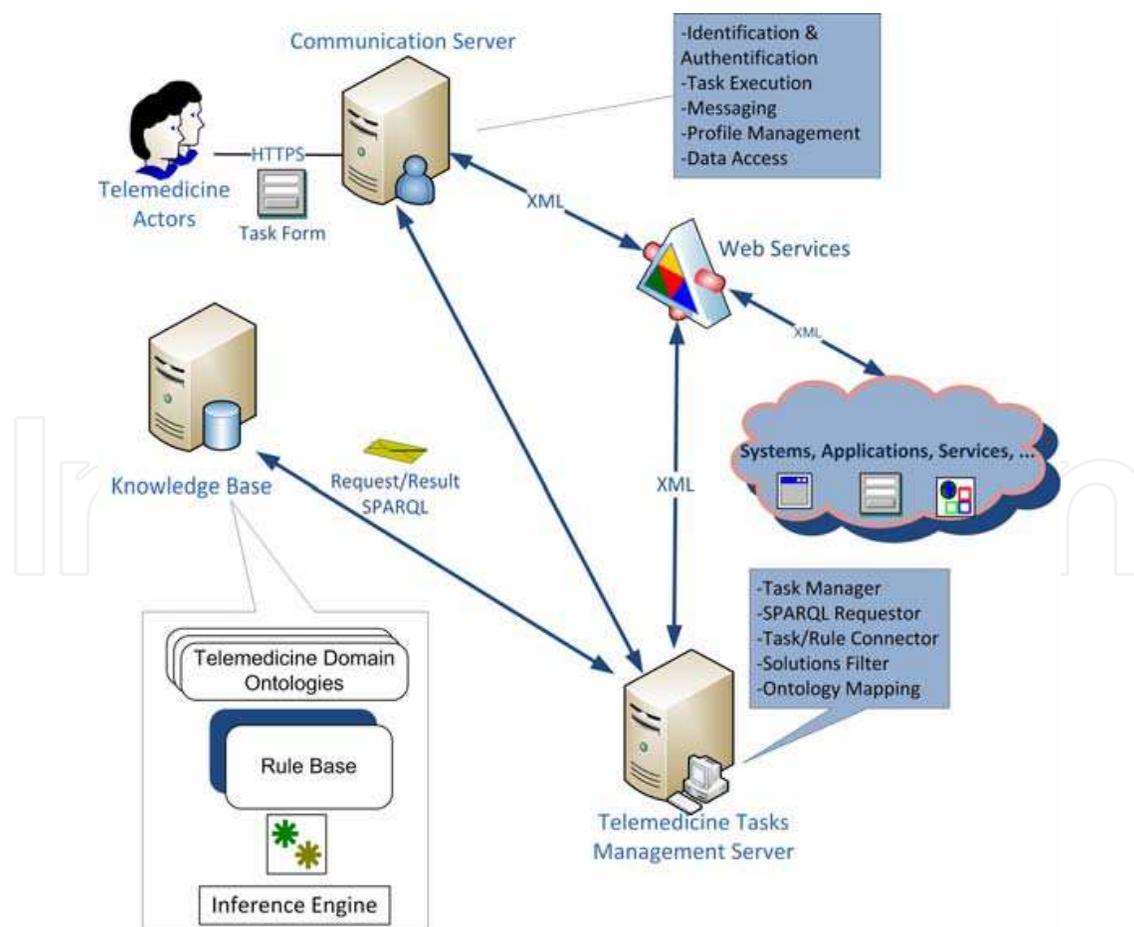


Fig. 3. General overview of the T-TROIE technical architecture

In addition, the communication server plays the role of a web server that responds to the HTTP requests issued by the users during the interactions with the system. It visualizes the different tasks forms generated by the task management server, forms that will be filled by the users who can also exchange messages with other actors in the telemedicine domain and manage their profiles. Moreover, the communication server allows other entities, i.e. systems, applications and services, to communicate with the T-TROIE system via web services protocols.

4.2 The task management server

The Tasks Management Server (TMS) is based on the W3C SPARQL Query Language for RDF (Prud'hommeaux and Seaborne, 2008). SPARQL permits to retrieve data from the ontology through queries such as SELECT, CONSTRUCT, ASK and DESCRIBE. It returns the query results in RDF. The main role of the TMS is to perform the following tasks:

- Link the identified actors with the tasks they can perform, for instance, a RTM can perform a patient orientation task, but he or she cannot perform a task which requires medical skills.
- Configure the form of the selected task by setting the required parameters. For example, if the actor selects the task patient orientation, TMS integrates in the task form several parameters such as the accident time, date and location.
- Select the rules which the inference engine will apply to infer the solutions needed by the users.
- Generate XML messages encapsulating different types of medical data, viz heart rate, systolic and diastolic blood pressure, body temperature, etc.
- Filter the solutions inferred by the inference engine according to different contextual factors related to location, actors' terminal technical characteristics, capability of human or material resources, etc.

4.3 The telemedicine knowledge base

The backbone of T-TROIE is the telemedicine knowledge base. As depicted in figure 3, this server consists of a set of interrelated ontologies describing the telemedicine domain, a rule base and an inference engine. We detail these components in the following sections.

4.3.1 Telemedicine domain ontologies

The ontologies we have created represent physical entities in the telemedicine domain such as Organization, Actor, Patient, Clinical Status, Resource and Location, as well as abstract entities such as Task, Service, Process, Message and Parameters. Figure 4 displays the different T-TROIE ontologies representing general concepts and their interrelationships in the telemedicine domain. Based on these ontologies, different contextual situations in various telemedicine scenarios can be easily handled. We provide hereafter a brief explanation of the main ontologies of T-TROIE.

- The Actor ontology represents classes of individuals such as healthcare professionals, i.e. General Practitioner, Specialist, Nurse, Emergency Physician, RTM, etc. A healthcare professional has the following data type properties: ID, name, general domain, specialty, location, etc.
- The Organization ontology describes healthcare institutions, i.e. hospital, medical center, insurance company, etc.

- The Resources are classified in two main classes: the material resource class, e.g. logistics, medical equipments, etc, and the communication resource class, e.g. server, laptop, smart phone, etc. The communication resource sub-ontology also describes resource properties such as brand description, memory size, screen size, resolution, embedded telecommunication technology, etc.
- The task ontology represents any activity to be performed by any actor in the telemedicine domain, whatever the actor is: a healthcare professional, a non medical staff, a patient or a patient's relative. The telemedicine tasks are classified in multiple categories, i.e. emergency, tele-consultation, tele-expertise, tele-radiology, etc.
- The Electronic Health Record ontology contains patient demographic information and patient medical data including medical history, allergy, risk factors, diagnostic summaries, ongoing pathology and treatment, etc.

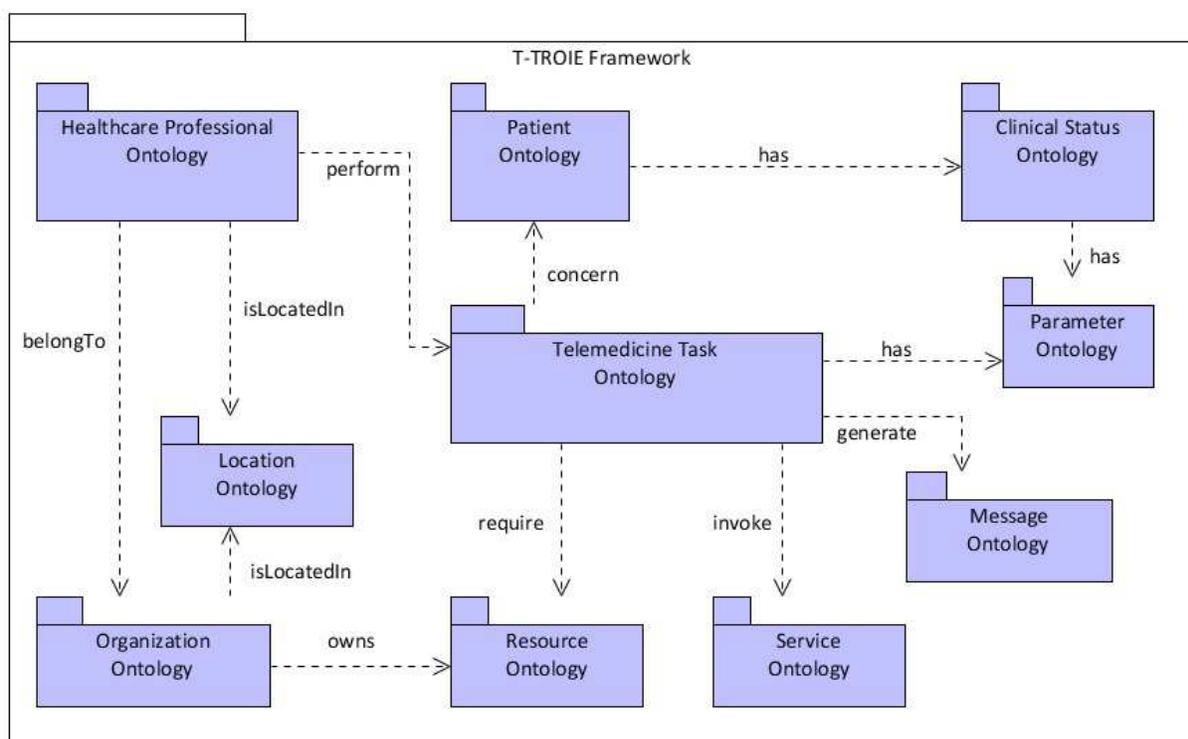


Fig. 4. T-TROIE ontologies and their interrelationships for the telemedicine domain

4.3.2 Rules for telemedicine tasks management

The rule base includes logical statements that specify how to handle the contextual situation by linking the context's elements such as the actors' profiles, the type of task, the patient clinical status and the resources required by the tasks. We distinguish two rule categories: (1) the management rules applied to infer the knowledge related to healthcare professionals, the telemedicine tasks, the different resources needed by the tasks and the organizations that manage or own these resources, (2) the communication rules enabling the designer to optimize message exchanges among different healthcare actors. The system designer defines a messages transmission policy including messages transmission priority levels according to the task type and to the actor's profile. For instance, messages generated by the patient orientation task have a higher priority level than the ones generated by a task like tele-

consultation. In addition, messages generated by the tasks performed by an emergency physician or a RTM have a higher priority level than the messages generated by the tasks performed by a nurse. We provide rules examples in section 5.

4.3.3 Rules and context based reasoning

One of the key features of ontologies is that they can be processed by a reasoner which supports the decision-making process and provides the knowledge base with the capacity of reasoning by applying defined rules. Various existing logic reasoning mechanisms can be exploited to deduce decisions that shall support the tasks management in telemedicine applications. These decisions shall enable telemedicine processes optimizing the use of resources. Additionally, the decisions shall provide solutions to societal problems such as the patient orientation in emergency cases. An inference engine applies the defined rules using the knowledge represented by the ontologies to deduce facts related to the contextual situation. Furthermore, the reasoner allows to automatically infer the ontology classes hierarchy and easies ontologies consistency checking.

4.4 Web services based interoperation

Web services constitute an efficient way to access remote data. T-TROIE can communicate with other systems and applications via web services. Tasks may invoke several web services to retrieve data related to the patient, the resources and the environment. For example, in a task such as "Access to Patient EHR", the healthcare professional may need to access the patient's medical antecedents, current prescribed medicines, or risk factors. Patient medical data are distributed over multiple data sources, i.e. EHR hosts. Thus, the task "Access to Patient EHR" invokes the web services provided by the EHR hosts. Several issues concerning access rights, security, privacy, performance and ontologies mapping must be considered when using these web services.

5. T-TROIE realization and implementation

In this section, we briefly introduce the different tools which were used in the T-TROIE prototype implementation process. First, we present the protégé-based demonstrator which we have used to formalize the ontologies, define SWRL rules, carry out the rule-based reasoning and execute SPARQL requests. Next, we present an example of the graphic user interface of the web-based application.

5.1 Protégé-based demonstrator

We have used the Protégé version 3.4 Development Environment (PDE) (Protégé, 1997), for building the ontologies of T-TROIE, to define the data entry forms, and use this forms to acquire data as instances of the ontologies.

OWL has three increasingly-expressive sublanguages which are OWL-Lite, OWL-DL (Description Logics), and OWL-Full. To formalize the telemedicine domain ontologies we have used OWL-DL, which is much more expressive than OWL-Lite and includes additional DL that are flexible to automated reasoning. In OWL-DL, there are two main types of properties that can be defined. The first type is object property, e.g., *Organization owns Resources*. The second type is data type property, e.g., *Actor has Specialty*. The DL extension provides OWL with a rich set of primitives, i.e., intersection, union, complement, etc. It allows the ontology designer to define restrictions and conditions on the ontology classes. It

is therefore possible to automatically determine the classification hierarchy and check for inconsistencies in an ontology that conforms to OWL-DL. To achieve this objective, we have used Pellet Reasoner (Pellet, 2007), which can be directly called from PDE, to check the ontologies consistency and to infer the classes hierarchy.

In fact, OWL has certain limitations which are related to the definition of composite properties. Efforts have been made by the W3 community to increase the expressiveness of OWL, particularly by developing a rule description language for the semantic web. W3C now recommends to use the Semantic Web Rule Language (SWRL, 2004), a combination of OWL-DL and OWL-Lite. We have used SWRL to create the rules used in our Telemedicine Task Ontology. The rules are written as antecedent-consequent pairs. In SWRL terminology, the antecedent refers to the rule body and the consequent refers to the head. The head and body consist of a conjunction of one or more atoms.

The rules definition process is an essential step in knowledge-based systems building. In T-TROIE, we have used the SWRL-TAP Protégé plug-in to manage the SWRL rules. Indeed, SWRL rules make T-TROIE ontologies semantically rich and facilitate the automation performed by the inference engine. We provide hereafter three examples of SWRL rules we have defined using SWRL-TAP to support tasks execution in the telemedicine domain.

Rule 1:

```
tele-onto:Task(?tele-onto:task) ^ tele-onto:Patient(?tele-onto:patient) ^ tele-
onto:Heart_Attack (?tele-onto:heartAttack) ^ tele-onto:Concernes(?tele-onto:task, ?tele-
onto:patient) ^ tele-onto:hasStatus(?tele-onto:patient, ?tele-onto:heartAttack) ^ tele-
onto:Coronagraphy_Equipment(?tele-onto:coronaroEquip) ^ tele-
onto:availability(?tele-onto: coronaroEquip, true)
→ tele-onto:requires(?tele-onto:task, ?tele-onto: coronaroEquip)
```

Rule 2:

```
tele-onto:Task(?tele-onto:task) ^ tele-onto:Patient(?tele-onto:patient) ^ tele-
onto:Heart_Attack(?tele-onto: heartAttack) ^ tele-onto:Concernes(?tele-onto:task, ?tele-
onto:patient) ^ tele-onto:hasStatus(?tele-onto:patient, ?tele-onto: heartAttack) ^ tele-
onto:IntensiveCareUnit(?tele-onto:icu) ^ tele-onto:availability(?tele-onto:ice, true)
→ tele-onto:requires(?tele-onto:tas, ?tele-onto:icu)
```

Rule 3:

```
tele-onto:Rescue_Team_Member(?tele-onto:rtm) ^ tele-onto:Task(?tele-onto:task) ^
tele-onto:performs(?tele-onto:rtm, ?tele-onto:task) ^ tele-onto:Message(?tele-
onto:message) v tele-onto:generates(?tele-onto:task, ?tele-onto:message)
→ tele-onto:messagePriorityLevel(?tele-onto:message, "High ")
```

Rules 1 and 2 describe the following context: if the telemedicine task, patient orientation in our example, concerns a patient who has as clinical status "Heart Attack", the inference engine, according to these rules, shall infer that this task requires as material resources a coronarography equipment and an intensive care unit to be available in the hospital where the patient will be hospitalized. Rule 3 represents an example of the message transmission

policy. When the RTM is performing a telemedicine task, then, the message generated by the task shall have a “high” priority level.

To perform the reasoning on the knowledge represented by the ontologies, we have used the Java Expert System Shell (JESS) protégé plug-in as an inference engine. There are three principal phases of reasoning with JESS. The first one converts OWL classes to JESS facts and converts SWRL rules to JESS rules. The second phase executes the reasoning. The last phase converts JESS inferred knowledge to knowledge described in OWL.

Figure 5 shows a snapshot of the Patient Orientation task interface, developed using Protégé, describing the task metadata, i.e. *Task Identifier*, *Task Description*, *Domain Speciality*, etc. This task is performed by a RTM and it concerns patient Mr.X being victim of a heart attack while skiing in the high mountains. Applying rules 1 and 2, the JESS inference engine infers that the patient orientation task requires as material resources a coronarography equipment and an available bed in an intensive care unit. As we have mentioned in the previously described scenario, Mr. X must be transported to an hospital which is close to the accident site and owns the needed material resources.

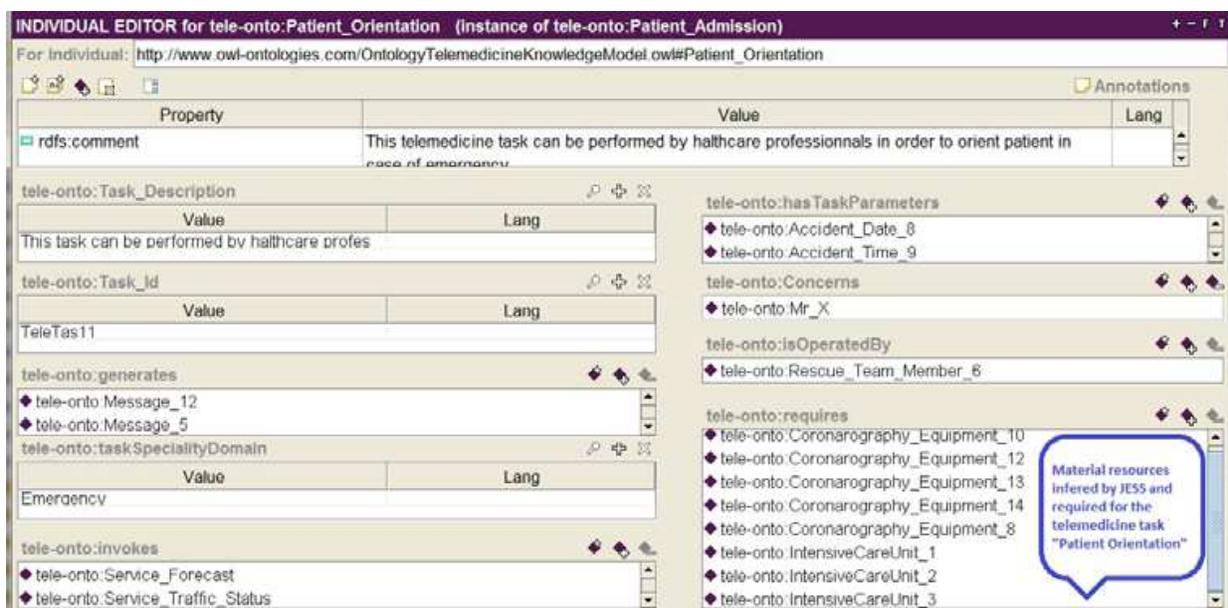


Fig. 5. Protégé-based interface representing patient orientation telemedicine task metadata including the required material resources inferred by the JESS inference engine.

A SPARQL query is executed to retrieve the appropriate hospitals, located in the same geographic area where the accident took place, and that have the required resources available (Figure 6). Once the RTM has selected one of these hospitals, messages, set with a high priority level, are generated and automatically sent to the selected hospital in order to notify it to be ready to receive the patient. Other services can be invoked to provide the rescue or the ambulance team with supplementary information that may be useful for the transportation like the road traffic status and the weather in case the patient is transported by helicopter.

5.2 T-TROIE web-base application

In order to make the application T-TROIE portable, usable and accessible from anyplace and on any material platform, we have developed a web-based prototype of T-TROIE

implementing the main functionalities and services. In the next sections, we present an overview of the technologies we have used for the development of the web-based application. Then, we describe the main web-based user interface of the T-TROIE prototype.

Organization	Material_Resource	Region	City
tele-onto:Cardiological Hospital Lyon	tele-onto:Coronaroagraphy Equipment	Rhone Alpes	Lyon
tele-onto:Cardiological Hospital Lyon	tele-onto:IntensiveCareUnit 1	Rhone Alpes	Lyon
tele-onto:Organization 3	tele-onto:Medical Equipment 16	Rhone Alpes	Grenoble
tele-onto:Organization 3	tele-onto:IntensiveCareUnit 3	Rhone Alpes	Grenoble
tele-onto:Organization 1	tele-onto:Coronaroagraphy Equipment	Rhone Alpes	Lyon
tele-onto:HEH	tele-onto:Coronaroagraphy Equipment	Rhone Alpes	Lyon
tele-onto:HEH	tele-onto:IntensiveCareUnit 2	Rhone Alpes	Lyon
tele-onto:Organization 12	tele-onto:Coronaroagraphy Equipment	Rhone Alpes	Chambery
tele-onto:Organization 11	tele-onto:Coronaroagraphy Equipment	Rhone Alpes	Annecy

Fig. 6. Example of a SPARQL query used to sort out the list of hospitals which have the resources required by the patient orientation telemedicine task and the location of these organizations.

5.2.1 Overview of used technologies

For the T-TROIE prototype implementation, we have used the Java Object Oriented Programming language. Indeed, thanks to its portability and platform independence, Java enables applications to be executed independently of the hardware and the operating systems on which these applications are installed. In addition, we have used the RDF-based Jena API, developed by Hewlett-Packard (HP) (Jena 2009), which allows us to overcome the programming related to the syntactic analysis (parsing) and the writing of specific syntaxes (serialization). It facilitates the development of tasks and also allows us to focus on operations on the ontologies at a high level of abstraction, e.g. classes definition, ontologies instantiation, data-type and object-type properties setting and instances management.

The Servlet technology, Java Servlet API, has been used to handle the client HTTP requests. Multiple Servlets have been developed to create instances and to initialize them into the ontologies. Other web technologies like HTML, JavaScript, JSP (Java Server Page) and a Tomcat server have also been used for the development of the T-TROIE web application.

5.2.2 Web interface

Figure 7 displays the graphic user interface of the T-TROIE web-based prototype of the architecture presented in section 4, implementing the main telemedicine tasks used in hostile environments, i.e. Patient Orientation, Tele-expertise, Tele-consultation, and Access to medical data. The first step is the user identification (healthcare professionals, RTM, or patient relatives) in order to take advantage of the T-TROIE functionalities and to launch the tasks that are relevant with the user's profiles.

Once the user is identified, he or she can click, for example, on the task "patient orientation". A form related to this task appears asking the user to initialize data and information related to the running task (Figure 8). The users then enter the required data and submit the task form. Then, T-TROIE generates a list of hospitals which have the material resources required for the patient hospitalization, as we have seen in figure 5. In addition to the telemedicine tasks, healthcare professionals can manage their profiles and exchange messages with other telemedicine actors.

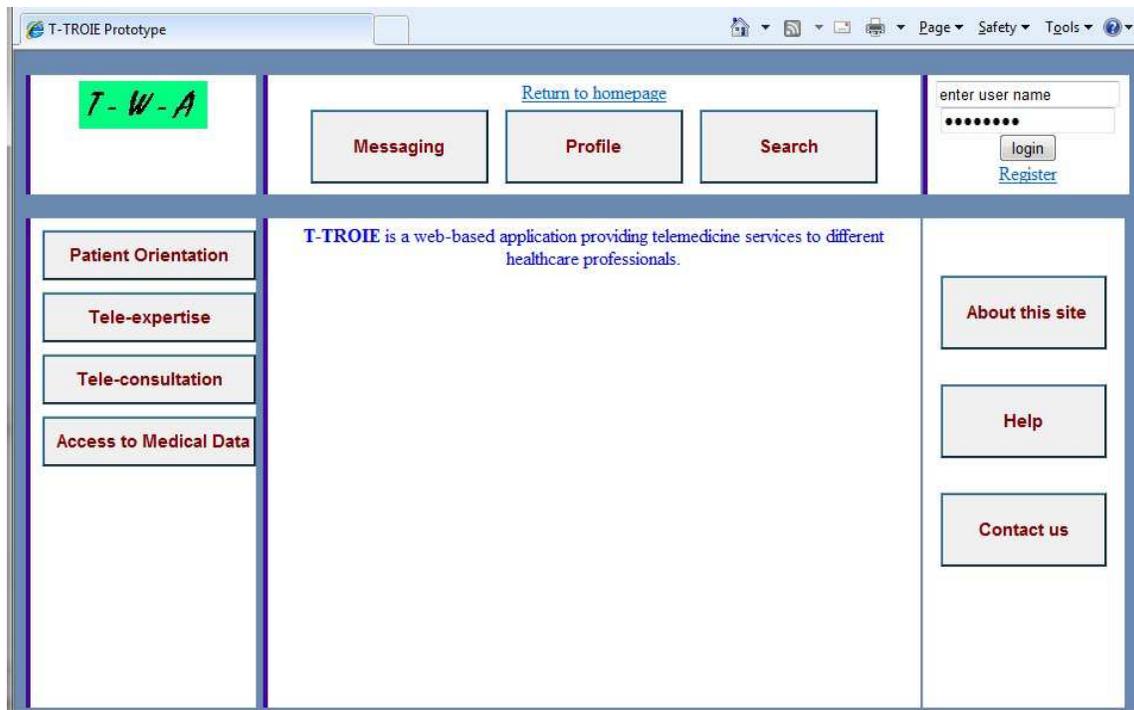


Fig. 7. Screenshot of the T-TROIE prototype web interface

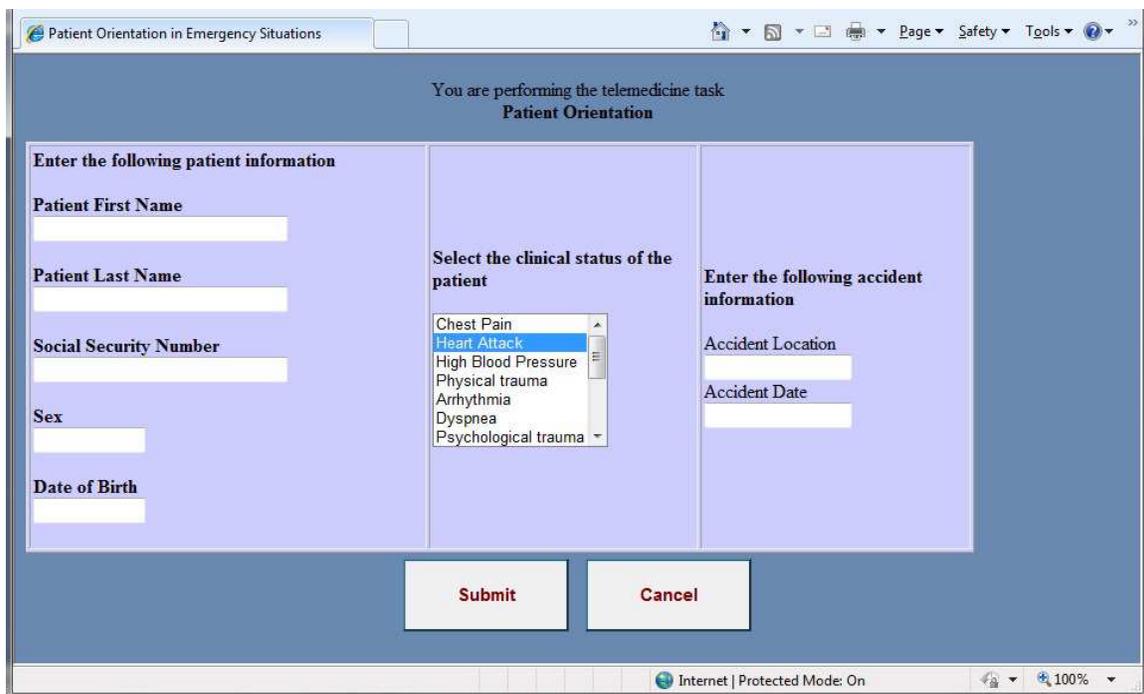


Fig. 8. Patient orientation task form example

6. Discussion

Numerous studies have reported about cases of cardiac death among sportsmen and active citizens, while others have demonstrated the relationship between mortality and the time delay to an appropriate treatment of the heart diseases (De Luca et al. 2004).

In general, the person who provides the first aid to a patient being subject to an accident or health troubles does not have the knowledge and the skills needed to take the appropriate decisions in terms of patient hospitalization. In addition, when a person is victim of a heart attack, by default, the ambulance service takes him to the nearest emergency center. This center may have the resuscitation equipment but it is not always able to perform an angiography, due to the lack of the needed resources. In this case, the ambulance team has to search another hospital which has the material and the human resources required by the angiography intervention and transfer the patient to this hospital. In some cases, patients die before arriving to the appropriate hospitals.

The high mountains or isolated areas emergency scenario example we presented as an illustration of such societal requirements demonstrates the need of providing an efficient and high quality tele-assistance to non skilled first aid persons located next to the patient who is subject to a health accident. Thus, it is extremely important to have a knowledge-based tool which links multiple telemedicine tasks with different types of resources required by these tasks, taking into account the availability and the capability of these resources. The T-TROIE knowledge-based telemedicine system we have developed answers the previous requirements. It has the capability to infer solutions adapted to different contexts in which multiple telemedicine tasks are performed.

The T-TROIE demonstrator has shown that the proposed knowledge-based architecture facilitates the design of complex medical tele-assistance processes and the management of telemedicine messages exchange and thus should contribute to the enhancement of the quality of pervasive telemedical services.

In contrast to other telemedicine solutions that were proposed to support pre-defined telemedical scenarios such as the continuity of care at home of patients with chronic diseases, the system we propose in this chapter aims to be generic enough for also being compliant with ubiquitous medical assistance in pervasive environment. T-TROIE is an open telemedicine system that may be easily adapted to further advances in healthcare. Its whole architecture being based on an high level of design by models, its functionalities can be persistently enhanced. Additional tasks can be easily included in the system, corresponding to other scenarios and environments. These tasks may be for instance Tele-expertise in cardiology, Tele-radiology and tele-dermatology, so that the healthcare professional can search which specialist or expert is available to provide a medical opinion or advice concerning medical images or bio-signals. Consequently, a sequence of solutions, including the profiles of available specialists or experts who are well qualified and capable to deal with the patient context, may be inferred by the inference engine and proposed to the requesting actor so that he can finally choose the one that best fits his own preferences.

7. Conclusion

In this chapter, we have presented T-TROIE, a knowledge-based system, supporting contextual situations handling in telemedicine environments, particularly in hostile environments like high mountains resorts. The proposed telemedicine system implements a knowledge base containing the basic interrelated ontologies in the telemedicine domain, such as healthcare professionals, healthcare institutions, resources, tasks, messages, and parameters.

The knowledge base we have implemented is generic, scalable and open to support different telemedicine applications and services. Representing the telemedicine activities by using an

ontology of tasks facilitates the automation of the telemedicine processes. The knowledge base links each telemedicine task with the clinical status and the social conditions of the patient, as well as it links each task with the needed resources to provide a high quality medical tele-assistance.

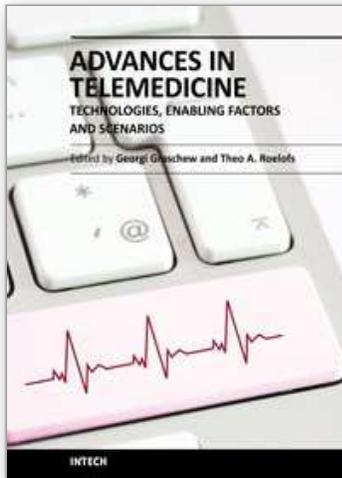
We have implemented a T-TROIE prototype in the telemedicine domain to solve societal problems such as Patient Orientation in case of an hospitalization. The designed telemedicine domain ontologies have been formalized using the ontology description language OWL-DL. The key feature of T-TROIE resides in its capacity to perform reasoning taking into consideration the availability and capability of different resources required to perform various tasks and processes. T-TROIE has the ability of handling different contexts of use taking into account, on one side the clinical status and conditions of the patient and, on the other side, the availability and the capability of the required material, communication, and human resources.

Thus, the objective of T-TROIE is to enable an intelligent management of the tasks, processes and resources in different pervasive telemedicine services and applications by providing actors in the telemedicine domain with an efficient decision making support tool.

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Advances in Telemedicine: Technologies, Enabling Factors and Scenarios

Edited by Prof. Georgi Graschew

ISBN 978-953-307-159-6

Hard cover, 412 pages

Publisher InTech

Published online 16, March, 2011

Published in print edition March, 2011

Innovative developments in information and communication technologies (ICT) irrevocably change our lives and enable new possibilities for society. Telemedicine, which can be defined as novel ICT-enabled medical services that help to overcome classical barriers in space and time, definitely profits from this trend. Through Telemedicine patients can access medical expertise that may not be available at the patient's site. Telemedicine services can range from simply sending a fax message to a colleague to the use of broadband networks with multimodal video- and data streaming for second opinioning as well as medical telepresence. Telemedicine is more and more evolving into a multidisciplinary approach. This book project "Advances in Telemedicine" has been conceived to reflect this broad view and therefore has been split into two volumes, each covering specific themes: Volume 1: Technologies, Enabling Factors and Scenarios; Volume 2: Applications in Various Medical Disciplines and Geographical Regions. The current Volume 1 is structured into the following thematic sections: Fundamental Technologies; Applied Technologies; Enabling Factors; Scenarios.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Ebrahim Nageba, Jocelyne Fayn and Paul Rubel (2011). A Telemedicine System for Hostile Environments, *Advances in Telemedicine: Technologies, Enabling Factors and Scenarios*, Prof. Georgi Graschew (Ed.), ISBN: 978-953-307-159-6, InTech, Available from: <http://www.intechopen.com/books/advances-in-telemedicine-technologies-enabling-factors-and-scenarios/a-telemedicine-system-for-hostile-environments>

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