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Integrating MDA and SOA for improving telemedicine services

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A B S T R A C T

Through telemedicine, the health sector has seized the opportunity offered by development of information and communications technology (ICT) such as the business or industrial sectors, but ICTs are constantly evolving. To benefit from technological progress it is necessary to adapt the computer applications to these technologies, however this operation is costly to health facilities especially in developing countries. In terms of scientific research, this observation explains the development of model-driven engineering of computer systems such as the Model Driven Architecture (MDA) approach. MDA is a computer design approach for the development of computer systems that considers separately the functional needs of technical needs of an application. MDA mainly uses the models and their transformations whose traces allow MDA to capitalize expertise in terms of technology and to ensure some rapid modernization of applications to new technologies which results in a significant productivity gain. Today there is a huge requirement worldwide in the interoperable services, in particular with regard to their valuable contribution to the collaboration ability of remote information technology systems. Service Oriented Architecture (SOA) is an interesting architectural pattern in which software components contribute to the collaboration and sharing of services. In this way, the principles of SOA are intended to ensure interoperability between heterogeneous and distributed applications. Web services are at the heart of SOA, which splits functions into different services, accessible over a computer network that enables users to associate and reuse them in the exploitation of applications. Health applications have a strong need to communicate with the remote institutions in order to provide the most relevant services to patients and to collaborate with other medical partners to solve complex tasks. For this purpose, the proposed research work shows how the paradigms of SOA and MDA can be configured to implement medical software applications on an e-health platform. The case study concerns the Telemedicine in French-speaking Africa (RAFT) project in which the joint use of MDA and SOA facilitates knowledge combination and reuse in the management of applications supporting a medical collaborative work environment.

1. Introduction

Telemedicine services are becoming more and more grow in health systems both in developed countries than in developing countries (Ekeland et al., 2012). Their operation requires to provide communication services via distance means

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promoting exchanges between collaborative actors and their heterogeneous and diversified resources (Doumbouya et al., 2014; 2015a, b, c, d). These services offer different features, but in some measures they are complementary to solve complex tasks (Sene et al., 2015; Kamsu-Foguem et al., 2015; Kamsu-Foguem, 2014a, b). To ensure better efficiency of telemedicine, the problem of interoperability of services provided by the information systems involved must be solve (Adebesin et al., 2013). This interoperability problem may create conceptual, technological or organizational barriers; these barriers may appear in the business, processes, services and data (Ducq et al., 2012). In those instances, solving the interoperability problem with the service is a major issue in the collaborative working (Lamprinakos et al., 2015). However, to overcome the technological aspects, it is important to place particular emphasis on conceptual modeling of a good abstraction level, especially with model driven approaches (Raghupathi and Umar, 2008). These approaches allow both to solve interoperability problems in the development and management of applications (Davies et al., 2014).

The network services have considerably affected and modified the collaborative work in information systems. This collaborative environment involves the usage of heterogeneous components whose interactions results in complexity. To answer this problem of heterogeneity and complexity, the integration of Model-Driven Architecture (MDA) (Model Driven Architecture, 2014) and Service-oriented architecture (SOA) (Sweeney, 2010) is an interesting avenue of research concerning information systems. The MDA approach proposes to define a business model independent of any technical platform and to generate a software application by its gradual transformation facilitating the business-information technology alignment. The SOA is an architectural principle allowing the communication (through the mediation) between different applications (independently of their environmental characteristics). Since the telemedicine acts are represented as applications to deal with complex medical situations, then the combination of MDA and SOA would facilitate communication and exchanges between these applications.

On the one hand, there is an increase of the means of communication between remote actors (e.g. main providers or specific users). On the other hand, there is too much data exchanged in network systems, in these exchanges the existence of related techniques can ensure good communications as regards the format of transmitted data (syntactic interoperability). However there are few means of implementation to ensure a proper understanding of the exchanged content (semantic interoperability). This applies in particular to the medical information systems in networks. According to the definition agreed upon by the World Health Organization, telemedicine is "*The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities*" (WHO, 1998).

Thus, telemedicine must consider the technical and human issues related to healthcare and patients' rights. Currently in developing countries, telemedicine technologies are assets, particularly to compensate for the lack of qualified medical staff in remote areas and also to overcome the technical problems for some medical analyses and operations (Kamsu-Foguem and Foguem, 2014a, b). Therefore, the telemedicine acts also help to facilitate the diagnostic and therapeutic activities through teleexpertise and teleassistance systems from health professionals without forgotten the remote training (e-learning) offered by some information systems such as the Network for Telemedicine in French-speaking Africa, abbreviated RAFT (Réseau en Afrique Francophone pour la Télémédecine) (Bediang et al., 2014). The telemedicine can be considered as a factor in territorial development, because it contributes to encouraging measures that support the geographic distribution and continuity of medical services and the retention of healthcare professionals in remote areas.

The rest of the paper is divided into the 5 sections. Section 2 presents a state-of-the-art review of the application of the SOA and MDA in the e-health; Section 3 provides background information on the SOA and MDA as well as the descriptions of concepts and technologies for each one. Section 4 presents the proposed methodology to highlight the different steps of the desired features of target information systems. In Section 5 the outcomes of the projected application in the RAFT project for the management of crisis situation are illustrated. Section 6 focuses on the conclusion of the paper.

2. State of the art review of the application of the SOA and MDA in the e-health

Telemedicine applications are constantly growing; their integration with SOA and MDA is a major challenge to meet the requirements of interoperability, modularity and extensibility of associated health services. However, the current interoperability provided by the health information systems is not enough (Uribe et al., 2015). An important point of interoperability is to ensure availability of specified services (e.g. patient's information retrieval and updating) at any time without geographic constraints. In addition, these services must be modular in order to guarantee some independent functions for each act of telemedicine. The services can also be extensible to take into account the opportunities of evolutions in health care information systems. The achievement of these characteristics (interoperability, modularity and extensibility) is essential for the good realization of remote medical services. For instance, the reduction of access time in the utilization of electronic health records can considerably impact the treatment of patients. In the same vein, an interoperable, modular and extensible environment provides means to ensure the consistency, traceability and coherence of distributed information recorded.

The methodology presented by Raghupathi and Umar (2008) highlights the conceptualisation and development for a health clinic system to track patient information using MDA. In this case, the described methodology is based on MDA for the development of health information systems which do not necessarily resolve the systems interoperability aspect. The prototype is made in the form of an entire MDA methodology for the specification and implementation of medical information systems. The transformation rules of models are applied to generate the specific prototype application. This is a type of methodology based only on MDA for the development of health information systems and it does not necessarily resolve the business interoperability of applications. Although this MDA based methodology would ensure the portability and scalability, meanwhile it is not sufficient to cover the interoperability requirements.

The work of Batraa and its colleagues employs the Service Oriented Architecture (SOA) to facilitate the interoperability of health care information systems (Batraa et al., 2015). For instance, it allows the data exchanges between service providers (health structures proving various medical services) and the service customer (patient profile information). However, the described work does not capitalize the functionalities of applications in medical services for potential future reuse. . . . Furthermore, the accessing of service customer or service provider details is achieved efficiently with the benefit of a suitable procedure that reduces the search time during the information retrieval process from the databases. Nevertheless, the authors are not interested in the portability of the proposed application, which limits its migration ability for others platforms.

The cloud infrastructure architecture proposed by Gazzarata et al. (2015) adopts the combination of SOA paradigm with the indication of Healthcare Services Specification Project (HSSP) to provide a secure access to the Electronic Health Record (EHR). In fact, the HSSP is a joint initiative between Health Level7 (HL7) and the Object Management Group (OMG), which had developed methodologies and deliverables with the motivation to enable a Semantically Interoperable Service-oriented Architecture for Healthcare (Kawamoto et al., 2009). However, it is difficult to evaluate the real implementation of this proposed architecture that is only explained in the interactions diagram for a secure access to EHR resources. The application of an integrated MDA–SOA approach is needed to encourage adaptive modeling strategies separating the context and software view and minimize the time-consuming process of developing in information systems. It is desirable also to facilitate the potential reuse of analyses with associated reasoning at conceptual and technical levels on important aspects of information systems. Therefore, some experience feedback processes with generated lessons learned can be included in information systems development (Schlieter et al., 2015). So, we can best meet the dynamic user needs and address the requirements of the technological changes for the delivery of more efficiency and service improvement from information systems working with heterogeneous components included in distributed and complex environments.

Flexibility and interoperability are two very coveted features in the development of enterprise information systems (McCoy and Plummer, 2006): flexibility refers to the company's ability to act and respond to the changes of a dynamic and efficient way and interoperability is the technical capacity of different applications organization to cooperate without conflict system, software or content.

3. SOA and MDA

The MDA and SOA technologies are used for the implementation of the proposed approach. The technical aspects are presented below:

3.1. The Model Driven Architecture (MDA)

In 2000 Object Management Group OMG adopted a framework, the Model Driven Architecture or MDA initiative as a software development approach to system-specification and interoperability based on the use of formal models (Model Driven Architecture, 2014). It separates the system functional specification of to its implementation specification on a given platform. The MDA approach allows for the elaboration of a generic modeling that can be used on multiple platforms through standardized projections. The implementation of the MDA is entirely based on the models and their transformations. For this purpose, MDA defines an architecture specification structured independent models platforms (PIM) and specific models (PSM).

The architecture of MDA is divided into four layers. The OMG is based on several standards. In the center, is the standard UML (Unified Modeling Language) (OMG, 2015a), MOF (Meta-Object Facility) (OMG, 2015b) and CWM (Common Warehouse Metamodel) (OMG, 2003). In the next layer, there is also a standard XMI (XML Metadata Interchange) (OMG, 2015c), which allows the dialogue between the middleware (Java, CORBA, .NET and web services). The third layer contains the services that manage the events, security, directories and transactions. The last layer offers specific frameworks in scope (Finance, Telecommunications, Transportation, Space, healthcare, e-commerce, and manufacturing) (see Fig. 1).

In the proposed approach, the field of study is healthcare which is a global challenge because the principle of equitable access to health care is not a luxury but a right for all. However, the Constitution of WHO (1946) indicates that good health is a state of global physical, mental and social well-being and not only the nonexistence of disease or infirmity (WHO, 1946). WHO's main concern in the area of health systems is moving on the way to worldwide health coverage. This work shares the WHO's ideals which are to promote an universal health access including the use of ICT in the medical community to facilitate the collaborative working relationships of health stakeholders for the key purpose of improving the medical management of patients.

The main purpose of MDA is to develop models of functional requirements separately from any implementation. It provides guidelines for the code generation through model transformations, derivations and successive enrichments. The main models are:

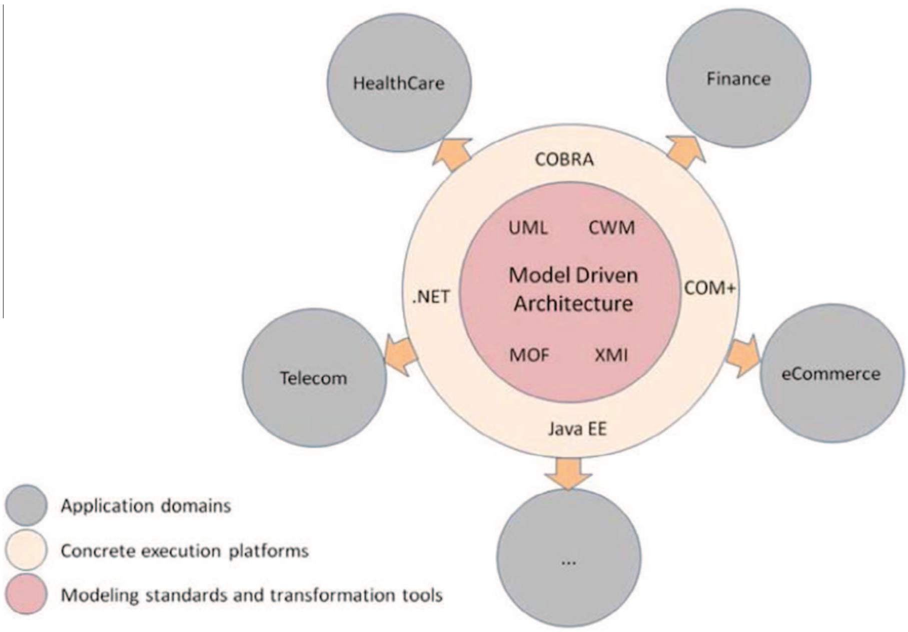

Fig. 1. The Model Driven Architecture (Model Driven Architecture).

- *CIM (Computation Independent Model):* it describes the concepts of business activity, the expertise of processes, terminology and rules (high level) and is modified only if the knowledge or business needs change (throughout the life cycle of a project). It is independent of any computer system.
- *PIM (platform independent model):* It characterizes a conceptual design achieving the functional requirements. It describes the system irrespective of any technical platform and any technology used to deploy the application and consists of UML (Rumbaugh et al., 2004) class diagrams (with constraints in OCL) (OMG, 2014).
- *PSM (Platform Specific Model):* it describes the technical details related to the implementation of a platform. It is used to generate the executable code executable by the specific technical platforms.

In the MDA approach, starting from the CIM to the source code, there are different types of model transformations (Fig. 2) using various transformation languages such as: ATL (Atlas Transformation Language) (Atlas Transformation Language, 2006), YATL (Yet Another Transformation Language) (Patrascoiu, 2004), QVT (Query/View/Transformation) (OMG, 2015d), BOTL (Bidirectional Transformation Object Oriented Language) (Braun and Marschall, 2003).

As a result, the MDA approach is a process of successive transformation of CIM, PIM and PSM models until the generation of the target application's source code (executable files). By saving a copy of the considered model at each stage of the transformation process, the reverse engineering processes are possible.

3.2. Service Oriented Architecture (SOA)

The fundamental principle of SOA is an architectural pattern in which application components provide services (i.e. logical representations of activities with specified outputs) to other components via a computer network and independently of any technology or product. A Web service is a software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format specifically Web Services Descriptions Language (WSDL) (Chinnici et al., 2003). Other systems interact with the Web service in a manner prescribed by its

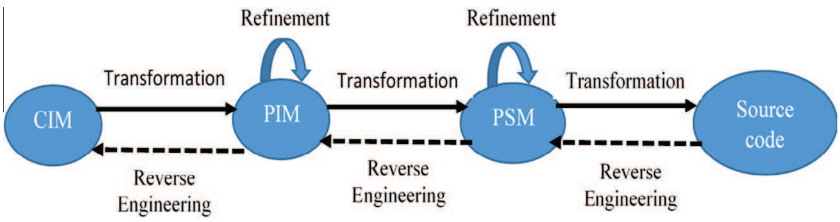

Fig. 2. MDA model transformation process.

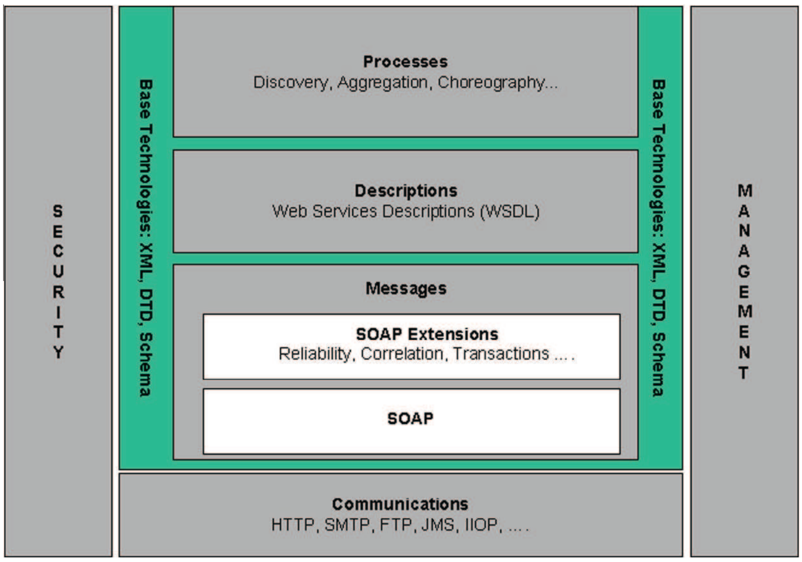

Fig. 3. Web services architecture stack (Booth et al., 2004).

description using Simple Object Access Protocol (SOAP) messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards (Gudgin et al., 2003; Bray et al., 2000). Web service architecture involves many layered and interrelated technologies. There are many ways to visualize these technologies, just as there are many ways to build and use Web services. Fig. 3 below provides one illustration of some of these technology families.

We distinguish four main layers. Service Transport layer is responsible for transporting messages between applications. Currently, this layer includes Hyper Text Transport Protocol (HTTP), Simple Mail Transfer Protocol (SMTP), File Transfer Protocol (FTP), and newer protocols such as Blocks Extensible Exchange Protocol (BEEP) (Booth et al., 2004). XML Messaging layer is responsible for encoding messages in a common XML format so that messages can be understood at either end. Currently, this layer includes XML-RPC (Remote Procedure Call) and SOAP. Service Description layer is responsible for describing the public interface to a specific web service. Currently, service description is handled via the Web Service Description Language (WSDL). Service Discovery layer is responsible for the centralization of services into a common registry and the provisions of easy publish/find functionality. Currently, service discovery is handled via Universal Description, Discovery, and Integration (UDDI).

There are three major roles within the web service architecture described in Fig. 4.

Service provider implements the service and makes it available on the Internet. Service Requestor is any consumer of the web service. The requestor utilizes an existing web service by opening a network connection and sending an XML request. Service registry is a logically centralized directory of services. The registry provides a central place where developers can publish new services or find existing ones. It therefore serves as a centralized clearing house for organizations and their services.

Infrastructure changes have taken place to improve the company's productivity but they can also upset all the existing IT systems that may imply a new modeling and high cost of updating. To overcome this problem, at each stage of the MDA transformation process, there is an archiving of different models of the system which can help to avoid a permanent fresh modeling when migrating to a new technology. So MDA allows significant time savings and better planning of updates concerning distributed systems. Basically, the joint use of MDA and SOA improves the interoperability of different technology of IT infrastructure and enables capitalization various models of the application system.

4. Methodology and approaches adopted

The adopted methodology is based on the idea of the combined use of the Model Driven Architecture (MDA) with the Service Oriented Architecture (SOA) to improve telemedicine services in developing countries.

The methodological principle is to export the various functionalities of the telemedicine applications as web services. This ensures the interoperability aspects between the telemedicine applications and all other applications on any platform wishing to communicate (exchange) data and information efficiently. This allows the connection with any device from any remote areas for enabling less-developed communities, both rural and urban, to use the services offered by telemedicine applications in developing countries. In addition, this approach of web services of e-health applications in developing countries is also based on MDA, which involves separating the independent and dependent aspects of the target platform. This approach aims to overcome the problems of complexity of health information systems and capitalize on the strong technology migration costs in a constantly changing environment. The proposed methodology includes the following five phases (Fig. 5):

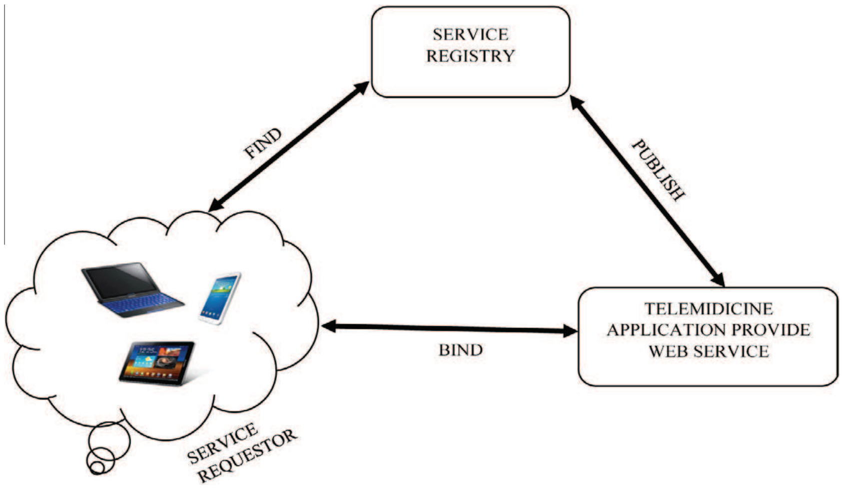

Fig. 4. Web services architecture.

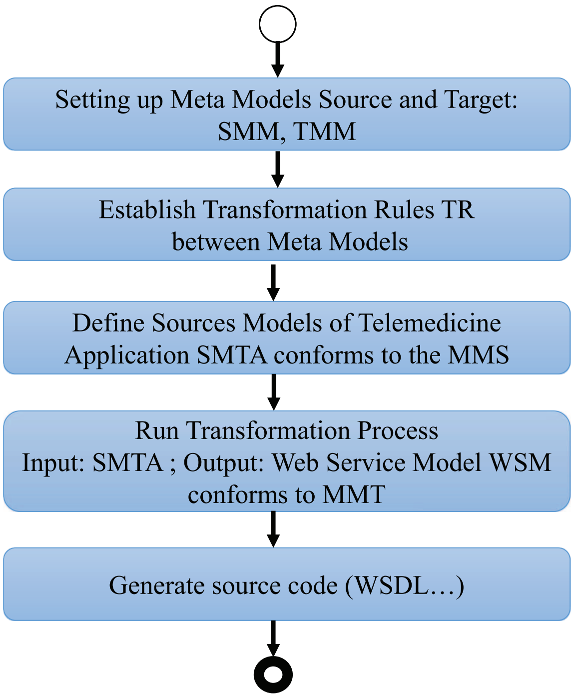

Fig. 5. The five steps are modeled with an UML activity diagram.

1. *Setting up Source Meta Model (SMM) and Target Meta Model (TMM):*
   In this phase, it is defined an appropriate Source Meta Model (SMM) that must comply with the functionality models of medical application (PIM), and it is also defined the Target Meta Model (TMM), but at the minimum level required for the compliance with the constraints imposed by the target platform, namely the platform in which the application will be implemented. In this case, the PSM specification concerns Web services. These Meta Models are made using UML or Enterprise Distributed Object Computing (EDOC) standards supporting distributed computing using MDA and SOA.
2. *Establishment of transformation Rules (TR) between the two Meta Models:*
   From the two meta-models defined above, it is established some transformation Rules (TR) between Source Meta Models (SMMs) and Web service Meta Model. Each element of the Source Meta Models (SMMs) must have its correspondence in the Target Meta Models (TMMs) (e.g. UML elements which are equivalent or similar to the WSDL elements). This step must be complete and consistent to enable a good automatic generation of source code.

3. *Definition of Sources Models of Telemedicine Application (SMTA) conforms to the SMM:*
   This phase is done after the selection from the existing medical application of the functionalities that must be exposed as web services and accessible to users. It is here that we model the functionalities of the medical application in accordance with Source Meta Models (SMMs) defined in step 1. This modeling is done by focusing only on the functionalities offered by the existing medical application without making any changes. This approach allows the capitalization of the expertise from the considered health structure on existing technologies.
4. *Running of the Transformation Process (Input is a SMTA and Output is a Web Service Model (WSM) conforms to TMM):*
   In the fourth phase, it is the execution of the transformation process that takes as input the SMTA to produce the corresponding Web Service Model (WSM) in an XMI (XML Metadata Interchange) file. This transformation process is written using the ATL language (Atlas Transformation Language) by reading the source PIM model (SMTA), and applying the transformation rules defined in step 2 to produce the PSM target Web Service Model.
5. *Generate source code (WSDL...):*
   In this last phase of transformation model, it is described the generation of source code (WSDL files) from the web services model. The WSDL files expose the functionalities of telemedicine applications and eventually deploy services generated for communication with any type of application, allowing them to be remotely accessible to users.

Our approach based on MDA and SOA is implemented to cope with the heterogeneity and complexity in the life-cycle management of telemedicine computer components and the constant evolution of computer technology. It is necessary to adapt medical applications to new technologies that are constantly evolving to satisfy changing needs of clients. In this view, it is important to use flexible approaches such as web services technologies that ensure interoperability between different applications and respond to many types of queries related to the evolving requirements of collaborative activities. Through this approach, it is possible to capitalize the expertise of the health structure and furthermore add a continuous improvement process of the information systems. As a result, the combination of MDA and SOA is a valuable means of achieving continual improvement in the development and modernization of telemedicine applications in developing countries.

5. Case study: RAFT project

RAFT was created in Africa more than a decade ago to sustenance health professionals working in remote areas and it has contributed to some important quantity of educational, clinical, and health activities during the last years (Bediang et al., 2014). Continuing training for health workers is an important factor in achieving the objectives of health services but the training costs are expensive to health facilities especially in developing countries. The use of ICT can significantly reduce the cost of training of health workers by facilitating access to geographically remote specialists with means to share medical information and have expert advices on complex medical situations. The main activities of the RAFT are: Tele-expertise activities and educational activities (Bagayoko et al., 2013; Vargas et al., 2014).

The tele-expertise is to allow a medical professional to seek advice of one or more medical professionals at distance according to their competencies or special skills on the basis of medical information related to the treatment of a patient. The e-learning is the practice of distance education targeting healthcare professionals. The figure below illustrates the methodology applied to the case study (see Fig. 6).

The key success of RAFT is called Dudal (Bediang et al., 2014). It is a computer tool, developed by the University of Geneva, it allow the transmission of sounds and images through on very low bandwidth. With Dudal, it is possible to broadcast remote

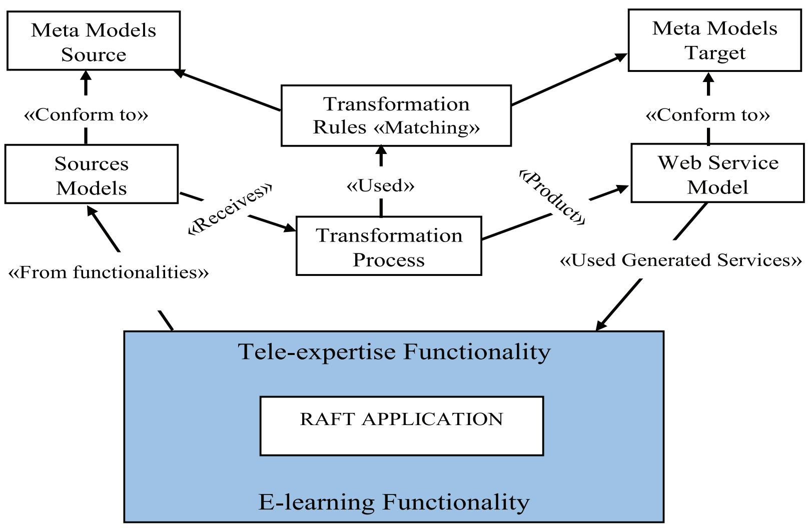

Fig. 6. The methodology applied to the case study.

courses with a speed not exceeding 25 kbits/s, which is ten or one hundred times less than an Asymmetric Digital Subscriber Line (ADSL) connection. With an alternative technology (band Ku), the monthly subscription fee is currently 300 euros.

This approach is a reverse engineering process for enhancements on the existence application, by adding new functionalities for the modernization of its technological capabilities to improve the performance of associated health services. This process allows capitalizing know-how in terms of technological management and can help promote some rapid innovations of applications by facilitating the adoption of new technologies with a significant productivity gain.

The process begins by setting up the Source Meta Model (SMM) and Target Meta Model (TMM). So, it is established some Transformation Rules TR between these two Meta Models. The model transformation operation can be adapted to the contextual requirements for better visibility and thus enhance understanding of structured specifications and improve compliance. This is done to explicitly outline the two major functionalities of the application as a service through the joint use of MDA and SOA. In accordance with RAFT functionalities, the definition of Sources Models is made in conformance with the Source Meta Models. The output of the transformation phase is the source code for the RAFT application. This is combined with the web service model that will be integrated into the RAFT application to outline its functionalities as services. The expected benefit from the obtained SOA-based services is an increase in remote accessibility of health services with an improved collaboration between health institutions.

6. Discussions

This work is aim to increase telemedicine systems with MDA and SOA technologies to improve the effectiveness of their communications on distributed hardware and software components. MDA and SOA approach has been introduced and used in some research for the integrated solutions. Studies have been made on the MDA and SOA in Cloud computing by Nodehi et al. and they propose a generic architecture for MDA-SOA based framework, which can be useful for developing applications which will require intercloud (i.e. cloud of clouds) interoperability. Rahmani and its colleagues have also used the MDA-SOA approach for development of an appointment making system (Torkaman Rahmani et al., 2006). Mardiana and its colleagues have (Mardiana and Araki, 2012) used the MDA-SOA approach to develop a web application that acts as an interface to integrate two existing academic information systems.

There are several approaches based on MDA and SOA technologies in literature but few in telemedicine in developing countries. Given the nature of low-income developing countries, MDA and SOA approaches represent a major interest, to take into account the heterogeneity and interoperability of the various electronic devices on the IT market. To avoid the high costs of developing telemedicine applications and possible technology migration, MDA and SOA approaches are increasingly inseparable, particularly in developing countries.

The proposed approach is a reverse engineering process for enhancements on the existing RAFT application, by adding new functionalities for the modernization of its technological capabilities to improve the performance of associated health services. This process allows capitalizing know-how in terms of technological management and can help promote some rapid innovations of applications by facilitating the adoption of new technologies with a significant productivity gain.

7. Conclusion and related works

The capacity of telemedicine application to share and exchange information (used in a more interoperable way) is important to facilitate the quality and effectiveness of healthcare services (Adebesin et al., 2013). In this regard, we have presented in this paper a joint approach using MDA and SOA for the development of telemedicine application in developing countries. Hospital management applications, knowledge sharing applications, Teleexpertise, e-learning applications are developed progressively. RAFT is a concrete example covering more than twenty countries (Bediang et al., 2014). The proposed approach allows outlining the functionality of telemedicine applications as services and based on the MDA concept. The advantage is to capitalize the business process and to facilitate interoperability with various applications on different platforms such as cellphone, tablets ... in remote areas (deficient in health personnel, or technical platforms, analyzes, operations). This allows better collaboration between users (patients and health professionals) and telemedicine services providers in developing countries, particularly in crisis situations such as the Ebola virus disease that shook the African continent.

As future work, we plan the use of semantic web services with ontologies to improve telemedicine in developing countries, the integration of assessment tools of telemedicine impact on patient's health, health systems, and socio-economic dimension in development pathways countries. Therefore, the proposed methodology will be extended to ensure the sustainability of telemedicine projects through recognition and valorization of acts of telemedicine, collaborative enrichment and taking into account socio-cultural differences. The future work also will also concern a proposal applying the used telemedicine methodology for the consideration of crises such as Ebola, natural disasters in developing countries.

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