Development of an Electronic Health Record Application using a Multiple View Service Oriented Architecture

Joyce M. S. França[1,2], Josimar de S. Lima[3] and Michel S. Soares[3]
[1]Federal University of Uberlândia, Faculty of Computing, Uberlândia, Brazil
[2]Federal Institute of Education, Science and Technology of Norte de Minas Gerais, Porteirinha, Brazil
[3]Federal University of Sergipe, Department of Computing, São Cristóvão, Brazil

Keywords: Service Oriented Architecture, Electronic Health Systems, Software Development, ISO/IEC/IEEE 42010, SoaML.

Abstract: Service-Oriented Architecture has been widely adopted in several domains in past years with the purpose of developing distributed applications. Within the health domain, integration of legacy systems by means of web services has been applied in order to develop complex applications. However, few approaches in this area treat complexity by delineating a software architecture to which applications must conform. In most cases in the literature, SOA applications in the health domain are documented using only one or two architecture views. This paper proposes a multiple view Service Oriented Architecture which is the basis for development of an Electronic Health Record (EHR) application. In order to develop the EHR, new requirements as well as current functionalities obtained from integrating legacy systems by means of web services were considered in a cohesive approach. Four architecture views, Scenarios, Business Process, Implementation and Logical View are presented. Each architecture view addresses one specific concern that organizes important concepts, facilitates understanding the system, and improves possibilities of communication between stakeholders. As a result, important software principles such as separation of concerns, component-based development and modularity are considered for development and integration of legacy systems in order to develop the EHR application to be deployed in a public hospital.

1 INTRODUCTION

Service-Oriented Architecture (SOA) has emerged as an architectural approach for developing distributed applications based on the concept of assembling services (Papazoglou et al., 2008). A service is a capability of the business organization that is implemented and made available over the Internet so that other applications can access it. In the past years, SOA has been widely adopted for developing distributed applications (Welke et al., 2011) (Marchetta et al., 2015). According to recent literature, SOA has been applied to develop applications in various domains (Soares and França, 2016), including automotive industry (Kabir et al., 2014), serious games (Carvalho et al., 2015), and learning platforms (González et al., 2014).

SOA has also been considered for developing health applications (Monsieur et al., 2012) (Cho et al., 2010) (Traore et al., 2016) (França et al., 2016). One health application that is considered very complex not only to develop but also to operate and maintain is the Electronic Health Record (EHR), which refers to software systems that stores health information about patients in a digital format. EHRs are used by different health professional teams, including physicians, nurses, radiologists, pharmacists, laboratory technicians and radiographers. Even patients can add information into the EHR, provided this is validated by physicians.

SOA has been chosen as the architecture basis for developing the EHR in this project due to the necessity of integrating legacy systems in a public hospital. Currently, the hospital has several legacy systems used for different purposes. Another issue is that the hospital maintains patient health records in hard copy papers manually written by clinicians. This is a problematic situation for two reasons: large amount of accumulated paper in several hospital rooms, and difficulty to retrieve patient records in order to check historical data and evolution of the patient's clinical status.

França, J., Lima, J. and Soares, M.
Development of an Electronic Health Record Application using a Multiple View Service Oriented Architecture.
DOI: 10.5220/0006301203080315
In *Proceedings of the 19th International Conference on Enterprise Information Systems (ICEIS 2017) - Volume 2*, pages 308-315
ISBN: 978-989-758-248-6

A well-known principle in system development is to describe in early stages of software development process the overall software architecture (Booch, 2007). According to ISO/IEC/IEEE 42010 (ISO 42010:2011, 2011), a software architecture is a fundamental concept of a software system in its environment embodied in its elements, relationships, and in the principles of its design and evolution. Typically, a software architecture description should include a number of architecture views (ISO 42010:2011, 2011). An architecture view (or simply, view) addresses one or more of the concerns held by one or a group of stakeholders.

In the literature, SOA has been considered to develop several health information systems, including clinical decision support (Cho et al., 2010) (El-Sappagh and El-Masri, 2014), telemedicine services (Traore et al., 2016), and EHR systems (Moor et al., 2015), (Fabian et al., 2015). Most often these studies present service architecture describing only one view (implementation view or process view) or even using natural language, code snippets and applications screens.

This paper aims to describe the software architecture of an EHR application based on SOA, which has been developed for deployment in a public hospital. Our application has been developed with focus on software architecture principles from its early design. Our architecture is described by means of multiple views, which is different from most other studies, as presented in the following section.

2 BACKGROUND AND RELATED WORK

According to ISO/TR 20514:2005 (ISO 20514:2005, 2005), EHR means a repository of patient data in digital form, stored and exchanged securely, and accessible by multiple authorized users. EHR, as a complex software system, contains any health, clinical or medical record in electronic or digital format in the context of patient care. A systematic literature review (Nguyen et al., 2014) proposed recently highlighted important details about EHR application worldwide. For instance, according to the authors, the adoption of EHR will increase significantly worldwide due to its several benefits. This review confirms the potential EHRs have to aid patient care and clinical documentation.

When system complexity grows, it is commonly advised to develop applications having a well-defined software architecture as basis (Bertolino et al., 2013). Architecture-based development has been applied for many years to solve issues such as interoperability between legacy systems and to help the development, integration and evolution of complex software systems (Garlan, 2014). However, in health information systems, such as EHR applications, software architecture is still not common sense, and when architecture is considered, it is based on a single view or a mix of views in only one picture.

Two studies presented in (Cho et al., 2010) and (El-Sappagh and El-Masri, 2014) propose SOA applications for clinical decision support. In both studies, only the implementation view of the EHR architecture is presented. One study in health domain, presented in (Traore et al., 2016), addresses telemedicine services and its related software architecture. The proposed architecture is, in fact, a model-driven approach to transform UML models into WSDL source code. Studies (Moor et al., 2015) and (Fabian et al., 2015) applied SOA concepts to develop an EHR system. In these works, the EHR architecture is described as a whole big picture, in which the views are considered together. For instance, in (Fabian et al., 2015) the architecture brings in the same picture dynamic processes, structural elements, and deployment infrastructure. In addition, application scope and which services should be implemented are not described. Work presented in (Gazzarata et al., 2015) proposes an EHR SOA application with focus on secure access, and presents the architecture using only the process view.

Most studies which address the implementation of an EHR using SOA concepts have focus on the application itself, but not on the architectural aspects for development. Even those studies which present the software architecture, only describes one or two views, or even a multiple number of views in only one box diagram, which may be confusing for most stakeholders.

Our proposal in this paper is to present an EHR application developed under SOA paradigm using multiple views to describe the software architecture, as preconized by ISO/IEC/IEEE 42010. Models presented in these views are described by means of UML and SoaML (OMG, 2012) diagrams.

3 A MOTIVATING CASE

The EHR system has been developed due to a demand from a public hospital. Three main constraints are considered in this EHR project. First, due to low budget for Information and Communication Technology in a public hospital, it is hard to apply resources for modernization of software applications. Thus, there is no possibility to start from scratch and discard all deployed legacy systems.

Second, lack of integration between current legacy systems makes duplication of data a common side effect. Most Hospital's legacy systems are not integrated and thus they do not meet many routine needs of hospital staff. There are many software systems for different purposes, including software to automate exams, to provide primary care, and also to register patient data. However, these modules do not interact with each other in an affordable way. Thus, data needs to be duplicated in two or more different systems.

Finally, important business rules have not yet been implemented in existing software systems, as discovered after mapping all current business processes in the hospital. For instance, patients' data are registered in and maintained as hard copies. Daily, hundreds of patients are treated at the hospital and all data and evolution are noted in physical medical records. In addition to this, these records should be kept for long periods (most often 20 years), to allow access to information stored on it at any time by the patient or his/her legal representative. Therefore, this scenario causes a big impact regarding storage space of this large amount of physical records. The large amount of paper occupies several rooms and it promotes difficulty in retrieving patient's records when clinicians need to consult past files to analyze patient evolution.

Due to the constraints presented before, the proposed solution is to use Service Oriented Architecture principles and techniques to gather all important information from legacy systems on services to be consumed by the EHR application.

After analyzing the current difficulty of retrieving patient data, this work proposes the development of an EHR application that maintains and automates access to information. The EHR application aims to store and provide medical records about patients in a public hospital. These patient data can be accessible by doctors, nurses, health professionals in general and also patients. Access to patient's data can be realized by devices such as desktops, laptops, tablets and mobiles.

Another important module implemented in the EHR application deals with centralizing and controlling appointments. Currently, appointments' management requires that a hospital employee has to access several systems. EHR application provides an important requirement that enables appointment scheduling in one single application. Therefore, the other systems will be accessed by the EHR through web services.

After performing all records verification procedures, patients with scheduled appointment are forwarded to the doctor's office according to the medical specialty needed. The appointment is carried out and the doctor is responsible for updating the patient's record in the EHR in accordance with doctor's observations. For each case, the doctor can prescribe medicines, request exams and mark further appointments.

4 ARCHITECTURAL VIEWS

According to ISO/IEC/IEEE 42010 (ISO 42010:2011, 2011), an Architecture View refers to a work product expressing the architecture of a software system from the perspective of specific system concerns. The EHR architecture proposed as follows is the basis to develop the application in a public hospital. The multiple views architecture is important to describe the different aspects of the architecture. This set of views is useful to describe the entire system for different stakeholders, including doctors, nurses, hospital managers and software developers, from different perspectives. Parts of the most representative views are presented as follows.

4.1 Scenarios View

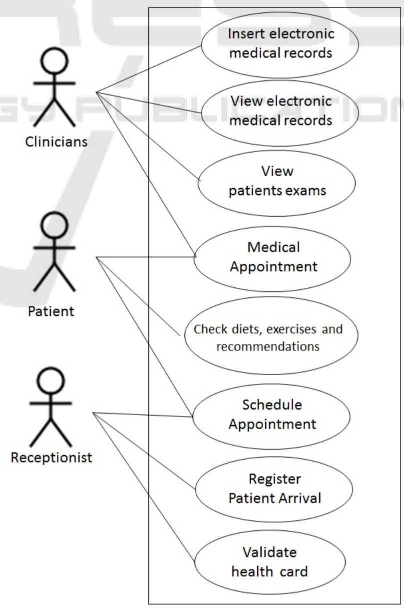

Figure 1: UML Use Case diagram.

One part of the EHR functionalities is presented in Fig. 1. The EHR developed in this research is able to schedule medical appointments, register appointments, store patient records, visualize entire patient records history, present results for patients' exams, and checking recommendations prescribed by doctors or health professionals. Several requirements and Use Cases were documented in this EHR project. However, due to space limitation, only a small number is listed as follows. This set of Use Cases can provide a glimpse of how the EHR improves automation of hospital business processes.

UC1 Authentication

- **UC1.1** User login.
- **UC1.2** User logout.
- **UC1.3** Password recovery.

UC2 Insert electronic medical records about patient.

UC3 View electronic medical records.

UC4 View patient exam results.

UC5 Schedule medical appointments.

UC6 Seek medical appointments scheduled for specific dates.

UC7 Schedule exams.

UC8 Seek exams scheduled for specific dates.

UC9 Validate health card.

UC10 Seek patient diets and medical recommendations.

4.2 Business Process View

Fig. 2 depicts an Activity diagram which presents the process for a medical appointment in the hospital. This process is detailed in the next paragraphs.

In most cases, appointments are scheduled by patients through the Basic Health Unit (BHU) located near their residence sector. Each patient has one BHU near to his/her house to request assistance when medical care is needed. Some basic health services are solved by clinicians in the BHU. Other more complicated health situations are forwarded to the public hospital.

On the appointment's day, patient is received in the hospital by an attendant at reception. The attendant is a hospital employee who has login to access the system and register the patient's arrival. Hospital attendant requests the number of the patient's Health Card, and then search in the EHR patient's registration that contains date of appointment and medical specialty.

Patients are received by the physician and then the appointment is performed. Physician reports patient records including clinical status and medicines prescription. Finally, physician describes exams and new appointments.

This process is responsible for scheduling and managing appointments. This is a small part of the EHR scope and, currently, it is required to access five different legacy systems to perform this task. In addition to this, patient record is manually written which makes it difficult further access by doctors. The developed EHR centralize this process, and also makes it possible to use only one system because the other systems are integrated by web services. Another advantage provided by the EHR is the fact that all information about patient health is stored in the system, which facilitates medical diagnostic.

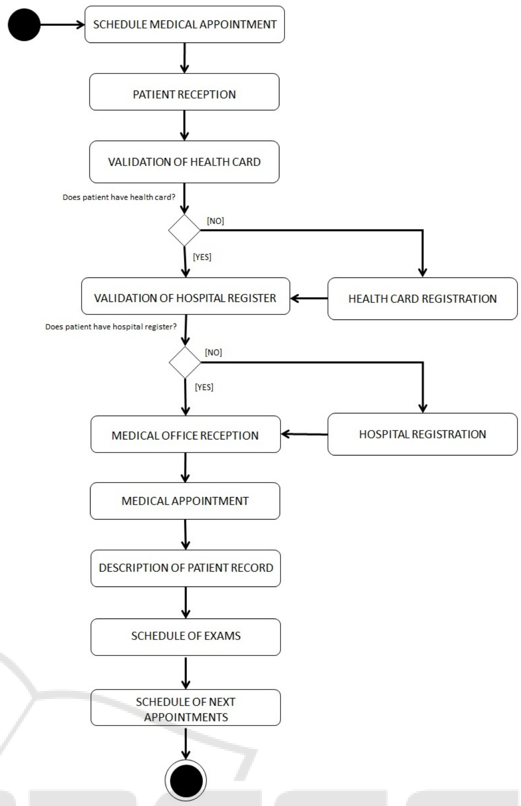

Figure 2: UML Activity diagram - Medical appointment process.

4.3 Implementation View

The EHR architecture proposes that users access the application by using computers (desktops, laptops) and also mobile devices such as tablets. Portability is an important requirement requested by health professionals. According to the systematic review (Nguyen et al., 2014) on EHR, portability and support for mobile work have emerged as important system quality attributes because several patients in hospitals have difficulties to move. Applications running on portable devices facilitates the transmission of information, for example, doctors can explain an exam result for a patient showing images from the mobile device.

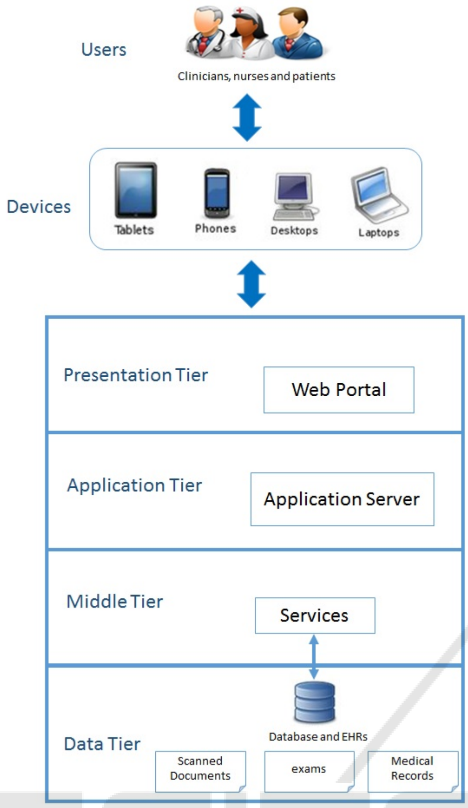

Figure 3: EHR Implementation View.

The EHR implementation view of the architecture proposed in Fig. 3 is designed as a multi-layered style. First layer, called Presentation, is about presentation components that provide or receive information to users. A web portal is developed to represent this first layer. According to previous decisions, as the EHR application can be executed on different devices, this layer must be independent from the lower layers.

Application layer is composed by an application server where the user information inputs will be collected and processed. This middle layer is composed by the services layer that resolves technical issues for the integration of different applications, solving problems of different data structures, connectivity to different protocols and specific needs of the involved systems. Typically, components transformation, and Routing Adapter are used.

The middle layer is composed by web services. Within Service-Oriented Applications, it is extremely important to clearly define some settings such as which services should be implemented, which systems are providers and/or consumers, definition of how to establish the interaction between systems and which data types will be supplied in requests and responses.

The Data layer abstracts the contact point of the SOA bus with legacy systems. Services providers will supply the EHR application with patient data requested by users.

Diagram depicted in Fig. 4 provides a global view of system services. In addition to this, SoaML Service Architecture diagram clearly presents all services that should be implemented, which systems are involved and which consumers and providers interact with the application. Figure 4 presents eight services, which are represented by an ellipse. Each service represents one functionality of a legacy system that is exposed in an Enterprise Service Bus (ESB) to be consumed by a system consumer, the EHR in this case.

Figure 4 presents ACONE, CADWED, AGHU, Medlynx and Imhotep, which are legacy systems involved in this project as providers of services. Each legacy system has important information about patients that will be consumed by the EHR. The EHR system has been developed for consuming several capabilities scattered across multiple systems. Within the SoaML Service Architecture diagrams it is possible to note that the EHR is a main consumer of data. These important data about patients is exposed by five legacy systems used as systems providers.

Another diagram presented in Figure 5, a SoaML Participant diagram, represents logical or real people or organizational units that participate in services architectures and/or business processes. The full specification of a participant includes ports for every service contract in which the participant participates within the services architecture. Fig. 6 presents EHR participant diagram showing the use of ports. Ports can be classified as ≪ **RequestPoint** ≫ or ≪ **ServicePoint** ≫. System providers offer functionalities exposing services and thus this participant type uses ≪ **ServicePoint** ≫ to represent services in participant diagram. On the other hand, ≪ **RequestPoint** ≫ is used when a system consumer requests a service.

Figure 5 allows to visualize all legacy systems involved and which services they should expose. Within Service-Oriented Applications, it is extremely important to clearly define settings such as which services should be implemented, which systems are providers and/or consumers, definition of how to establish the interaction between systems and which data types will be supplied in requests and responses.

4.4 Logical View

Logical view is described by means of two different and complementary diagrams, UML Class diagram and SoaML Participant diagram. The UML Class diagram, as depicted in Fig. 7, is applied as a basis for

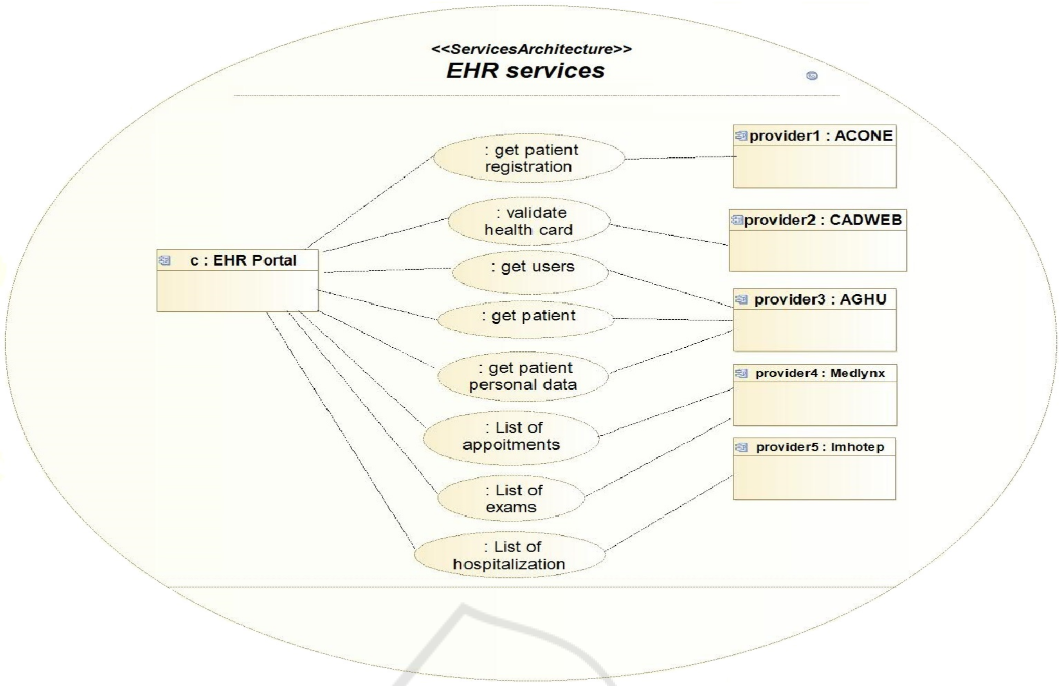

Figure 4: Service Architecture diagram representing legacy systems.

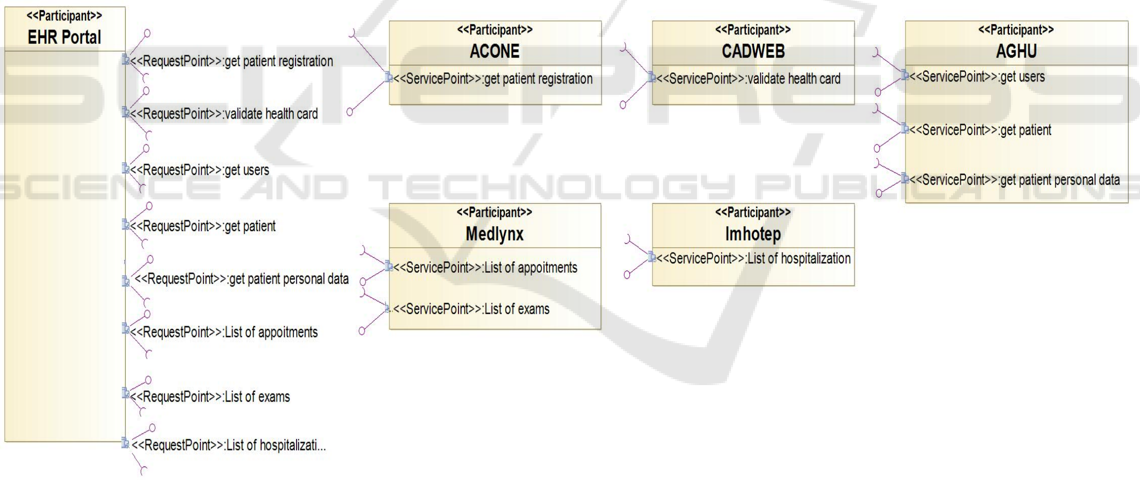

Figure 5: Participant diagram representing ports.

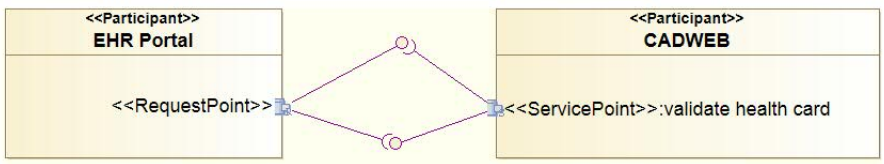

Figure 6: Data exchange between systems through services.

developing the EHR system. Fig. 6 presents another Participant Diagram that depicts two systems that can communicate with each other through a service. The SoaML Participant diagram describes this situation. This diagram has been chosen as it presents structural view of services.

The EHR is a consumer system that request for a valid health card service exposed by a legacy system

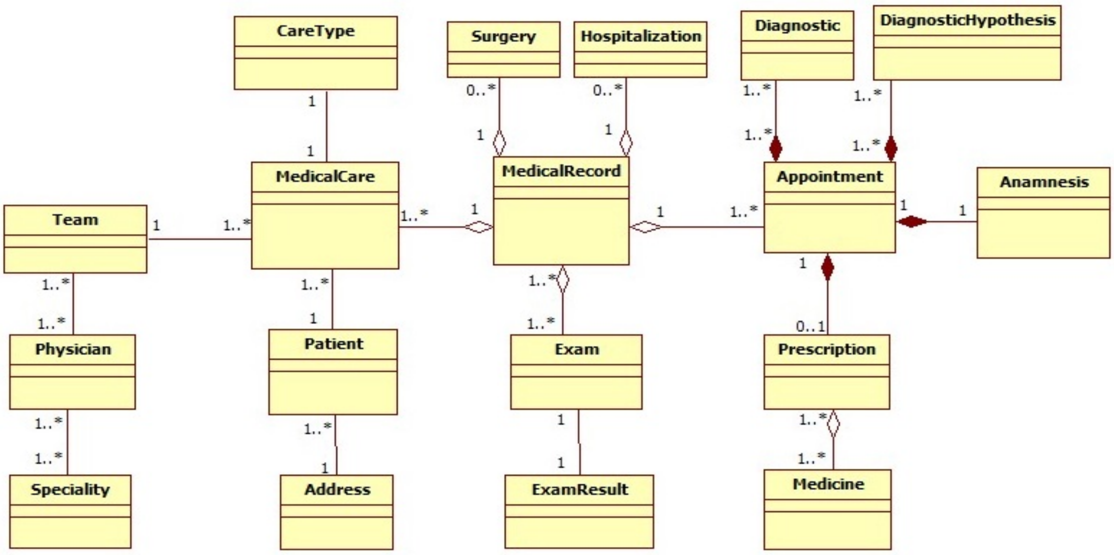

Figure 7: UML Class Diagram.

named CADWEB. EHR gives a request containing a health card number and CADWEB receives this provided number as request. Then, the valid health card service is executed and provides a confirmation as response that is captured by the EHR.

5 CONCLUSIONS

This paper presents an architectural description using multiple views for an EHR system based on SOA. The EHR application developed is a demand of a public hospital that has several legacy systems for different purposes. In most cases, literature proposes SOA application in EHR domain without addressing architectural concepts. As presented in Section 2, some studies propose EHR architecture using natural language and some using informal draws. This scenario can represent that there is focus on the application itself. However, in software development process, it is necessary to address architectural elements as well. Some other studies concerned on EHR architecture presents the software architecture by describing only one or two architectural views, or even two views described on the same diagram, making it difficult for most stakeholders to understand the architectural models.

Contrary to most other works found in the literature, this work proposed EHR architecture using multiple views. Four architectural views, Scenario, Business Process, Logical and Implementation, are presented to provide an overview of the development of a SOA application in the health domain. Each view presents different elements, improving separation of concerns. Software architecture is documented in multiple views in order to help stakeholders to better understand the future software system. In addition, architecture description using multiple views allows managing complexity and risks during software development.

This paper describes part of the EHR architecture, which is applied to gather requirements by hospital stakeholders such as doctors, nurses, receptionist and health professionals in general. The proposed architecture has been proven to be extremely important to validate EHR scope by stakeholders because they could understand what would be developed. Architecture views presented are important because, in general, hospital stakeholders are not experts in information technology technical concepts. Thereby, scenarios and business process views are fundamental to facilitate understanding of future system functionalities through diagrams such as Use Cases and Activity diagrams.

In addition, the proposed EHR architecture has been crucial for software developers. They clearly could understand through multiple scenarios, business processes, layers, and architectural decisions what should be implemented. Documenting software architecture facilitates the development but also further maintenance. As a conclusion of this case study, after development of the EHR application using SOA, it is clear that investing time and effort documenting the software architecture is beneficial to the system development process. Multiple architectural views enable most stakeholders to understand the project scope, even if they are not expert in software development.

ACKNOWLEDGEMENTS

The authors would like to thank the Brazilian research agency CNPq (grant 445500/2014-0) for financial support.

REFERENCES

Bertolino, A., Inverardi, P., and Muccini, H. (2013). Software Architecture-based Analysis and Testing: A Look into Achievements and Future Challenges. *Computing*, 95(8):633–648.

Booch, G. (2007). The Economics of Architecture-First. *IEEE Software*, 24(5):18–20.

Carvalho, M. B., Bellotti, F., Berta, R., Gloria, A. D., Gazzarata, G., Hu, J., and Kickmeier-Rust, M. (2015). A Case Study on Service-Oriented Architecture for Serious Games. *Entertainment Computing*, 6:1–10.

Cho, I., Kim, J., Kim, J., Kim, H. Y., and Kim, Y. (2010). Design and Implementation of a Standards-Based Interoperable Clinical Decision Support Architecture in the Context of the Korean EHR. *Int. J. of Medical Informatics*, 79(9):611–622.

El-Sappagh, S. H. and El-Masri, S. (2014). A Distributed Clinical Decision Support System Architecture. *Journal of King Saud University - Computer and Information Sciences*, 26(1):69–78.

Fabian, B., Ermakova, T., and Junghanns, P. (2015). Collaborative and Secure Sharing of Healthcare Data in Multi-Clouds. *Information Systems*, 48:132–150.

França, J. M. S., de S. Lima, J., and Soares, M. S. (2016). A Case Study on SoaML to Design an Electronic Health Record Application Considering Integration of Legacy Systems. In *40th IEEE Annual Computer Software and Applications Conference, COMPSAC 2016*, pages 353–358.

Garlan, D. (2014). Software Architecture: A Travelogue. In *Proc. of the on Future of Software Engineering*, FOSE 2014, pages 29–39.

Gazzarata, G., Gazzarata, R., and Giacomini, M. (2015). A Standardized SOA Based Solution to Guarantee the Secure Access to EHR. *Procedia Computer Science*, 64:1124–1129.

González, M. Á. C., García-Peñalvo, F. J., Forment, M. A., Mayol, E., and Llamas, C. F. (2014). Implementation and Design of a Service-Based Framework to Integrate Personal and Institutional Learning Environments. *Science of Computer Programming*, 88:41–53.

ISO 20514:2005 (2005). ISO 20514:2005 Health informatics, Electronic health record - Definition, scope and context. Technical report, ISO, Geneva, Switzerland.

ISO 42010:2011 (2011). ISO 42010:2011 Systems and software engineering Architecture description.

Kabir, M. A., Han, J., and Colman, A. W. (2014). SocioTelematics: Harnessing Social Interaction-Relationships in Developing Automotive Applications. *Pervasive and Mobile Computing*, 14:129–146.

Marchetta, P., Natale, E., Pescapè, A., Salvi, A., and Santini, S. (2015). A Map-Based Platform for Smart Mobility Services. In *Symposium on Computers and Communication, ISCC 2015*, pages 19–24.

Monsieur, G., Snoeck, M., and Lemahieu, W. (2012). Managing Data Dependencies in Service Compositions. *Journal of Systems and Software*, 85(11):2604–2628.

Moor, G. D., Sundgren, M., Kalra, D., Schmidt, A., Dugas, M., Claerhout, B., Karakoyun, T., Ohmann, C., Lastic, P.-Y., Ammour, N., Kush, R., Dupont, D., Cuggia, M., Daniel, C., Thienpont, G., and Coorevits, P. (2015). Using Electronic Health Records for Clinical Research: The Case of the EHR4CR Project. *Journal of Biomedical Informatics*, 53:162–173.

Nguyen, L., Bellucci, E., and Nguyen, L. T. (2014). Electronic Health Records Implementation: An Evaluation of Information System Impact and Contingency Factors. *Int. J. of Medical Informatics*, 83(11):779–796.

OMG (2012). Service Oriented Architecture Modeling Language (SoaML) Specification. Technical report, http://www.omg.org/spec/SoaML/1.0/PDF.

Papazoglou, M. P., Traverso, P., Dustdar, S., and Leymann, F. (2008). Service-Oriented Computing: a Research Roadmap. *Int. J. Cooperative Information System*, 17(2):223–255.

Soares, M. S. and França, J. M. S. (2016). Characterization of the Application of Service-Oriented Design Principles in Practice: A Systematic Literature Review. *Journal of Software*, 11(4):403–417.

Traore, B. B., Kamsu-Foguem, B., and Tangara, F. (2016). Integrating MDA and SOA for Improving Telemedicine Services. *Telematics and Informatics*, 33(3):733–741.

Welke, R., Hirschheim, R., and Schwarz, A. (2011). Service Oriented Architecture Maturity. *IEEE Computer*, 44(2):61–67.