Ontology-based enterprise architecture model analysis

Article · March 2014

DOI: 10.1145/2554850.2555176

Rudolf Mayer
TU Wien

José Borbinha
University of Lisbon

Artur Caetano
University of Lisbon

Ontology-Based Enterprise Architecture Model Analysis

Gonçalo Antunes[1]
goncalo.antunes@ist.utl.pt

Marzieh Bakhshandeh[1]
marzieh.bakhshandeh@ist.utl.pt

Rudolf Mayer[3]
rmayer@sba-research.at

José Borbinha[1,2]
jose.borbinha@ist.utl.pt

Artur Caetano[1,2]
artur.caetano@ist.utl.pt

[1]Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal
[2]INESC-ID, Information Systems Group, Rua Alves Redol 9, 1000-029 Lisboa, Portugal
[3]SBA Research GmbH, Favoritenstraße 16, 1040 Wien, Austria

ABSTRACT

An enterprise architecture provides views on heterogeneous domains, such as business processes, people, business rules, application components, and technological infrastructure. These views are defined according to specific concerns and need to be expressed with an adequate description language. This entails integrating the description languages as a means to address the multiple concerns but raises the challenge of keeping the models coherent, consistent and traceable. This work describes an application of ontology engineering to enterprise architecture. The contribution is an extensible architecture description language that includes an upper ontology that can be integrated with multiple domain-specific ontologies, each focusing on different concerns. The resulting integrated models can be automatically analysed.

Categories and Subject Descriptors: Applied computing [Enterprise computing]: Enterprise architectures; Enterprise ontologies, taxonomies and vocabularies. Computing methodologies [Knowledge representation and reasoning]:Ontology engineering.

Keywords: enterprise architecture, ontology, ArchiMate, OWL.

1. INTRODUCTION

Enterprise architecture (EA) is defined by Lankhorst as "a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and infrastructure, providing a basis for business-IT alignment" [12]. In model-driven enterprise architecture such alignment by relating the concepts that abstract the enterprise domains . Managing the dependencies between and within these models is crucial for supporting the communication between different stakeholders as well keeping the models consistent [8, 13].

Despite the efforts for developing comprehensive modelling approaches to enterprise architecture, it has been recognized that defining encompassing meta-models that simultaneously targets several domains has drawbacks[15, 4, 7]. Different organizations have distinct concerns and thus require specific information to be represented and extracted from the models. Thus it is a challenge to create an architecture description that is able to simultaneously manage the multiple concerns. Approaches that attempt to tackle this challenge include viewpoint orientation [10], situational engineering, as well as the integration and extension of meta-models [5, 11]. Ontology-based techniques have also been proposed [16, 2, 1, 9]. However, keeping such models coherent and checking their conformance is not straightforward [3]. So, there is a need for solutions that are able to address multiple concern environments. This paper describes an ontology-based approach to multiple concern model-based enterprise architecture. Its main contributions are (1) extension of enterprise architecture through the mapping of multiple domain-specific meta-models; (2) enforcement of coherence through ontological axioms; (3) verification of meta-model conformance against semantic rules; and (4) model analysis through the usage of inference and querying. This paper is organized as follows: section 2 briefly describes how ontology-based techniques are used to handle the extension and analysis of enterprise architecture models and section 3 shows an application of this proposal to a concrete scenario where ArchiMate is used as upper ontology.

2. ONTOLOGY-BASED ARCHITECTURE

The approach is grounded on a upper ontology where the core concepts are defined. This meta-model does not address any domain-dependent concerns. So, the upper ontology is termed domain-independent ontology (DIO). The DIO can be extended by several domain-specific meta-models, each represented as a domain-specific ontology (DSO). Each DSO addresses a particular set of concerns and is designed to have the minimum set of concepts required for describing its domain. Low-coupling and high-cohesion are the principles guiding the design of DSOs to minimize the dependencies between the DIO and DSOs .

The DIO and each DSO are integrated as a means to achieve traceability and cross-ontology analysis. Ontology integration makes use of model transformation, which involves defining a mapping strategy from a source to a target model [14]. The map may define a bijective 1:1 correspondence between the concepts of the two models. But mapping

SAC'14 March 24-28, 2014, Gyeongju, Korea.

deficiencies might occur [6]: a concept on the DSO may map to several concepts in the DIO (overload), not map to the DIO at all (deficit), or several concepts in the DSO may map to one concept in the DIO (redundancy). These deficiencies must be addressed when integrating the ontologies.

Each ontology can be analysed using reasoning or querying. Four types of analysis are possible: (1) *intra-DIO reasoning*, which is limited to the concepts of the DIO; (2) *intra-DSO reasoning*, which is limited to the concepts of a single DSO; (3) *cross-DSO reasoning*, when the analysis spans two or more DSOs; and (4) *cross DIO-DSO reasoning*, when the analysis targets the DIO and one or more DSOs.

3. CASE STUDY

This section describes the application of the ontology-based architecture to a case study, including the instantiation of the DIO, a DSO, along with examples of model analysis. The case concerns a regulatory organization that assesses and monitors the structural safety of large engineering infrastructures, such as hydroelectric power plants, dams and bridges. This is accomplished through tasks performed at different stages of the structure's life-cycle, ranging from project planning, construction, and operation, to the structure's retirement. A significant part of the operational monitoring is performed by an array of specialized sensors that measure the physical behaviour of the structure. This organization is also required to document and preserve the business processes, information systems and technology that support the acquisition, processing and storage of the data pertaining to each structure. Thus EA plays an important role as a means to manage these artefacts.

This case was partially modelled with the ArchiMate architecture description language (v. figure 1). However, some of the concerns of the organization cannot be addressed with this language, such as details about legal aspects and the sensor infrastructure. Their representation therefore requires using specialized domain-specific languages. The next sections describe how this was accomplished using the ontology-based approach.

3.1 The Domain-Independent Ontology

In this scenario the core concepts are constrained by the ArchiMate meta-model. The DIO is therefore an OWL-DL specification of ArchiMate's concepts and relationships. The result is a set of OWL *ObjectProperties* along with axiomatic and cardinality constraints as depicted in figure 2.

3.2 A Domain-Specific Ontology

One of the concerns of this case study is detailing aspects pertaining to the sensor domain using concepts from the SensorML[1] domain-specific language. However, such representation is out of scope of the ArchiMate language and thus requires a specialized description language. To do so, we created a specific ontology (DSO) that describes the concepts and relationships of the sensor domain. The class diagram depicted in figure 3 shows part of the classes and relationships defined in the sensor DSO. The concepts within this DSO were mapped to the ArchiMate DIO concepts. For instance, sensors are computational nodes and thus the *Sensor* class in the sensor DSO is mapped to the *Node* class in the DIO.

[1]http://www.ogcnetwork.net/SensorML

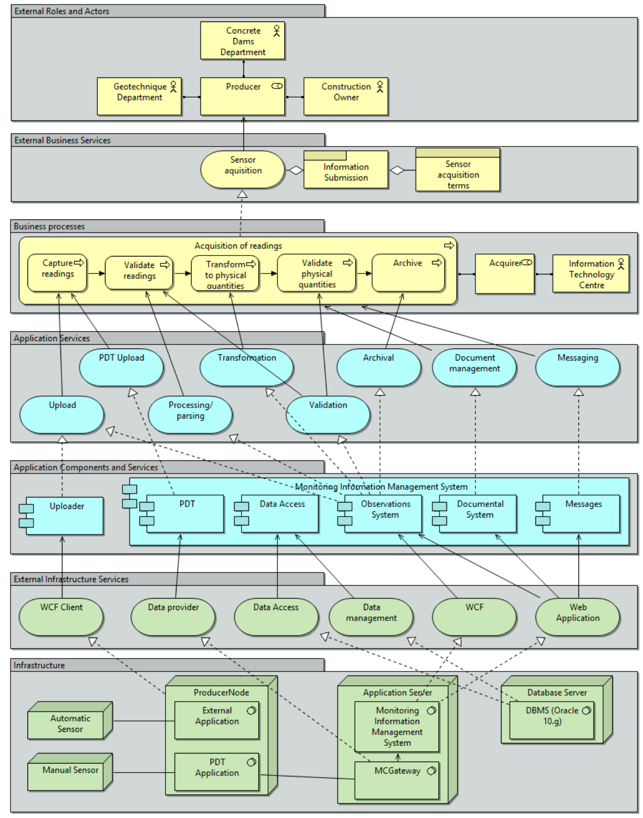

Figure 1: ArchiMate overview model of the business, application and technological concepts.

3.3 Model Analysis

The content of the model is analysed through the application of inference and querying to the ontologies. Inference is grounded on the capabilities of reasoners that operate over OWL-DL while querying is accomplished through SPARQL. One example of analysis is determining which technological infrastructure concepts are used by some business process. This implies traversing the model and determining which applications are used by the process and the technological infrastructure elements that realize these applications. This is a case of a intra-DIO analysis since the scope is limited to the ArchiMate upper ontology. Figure 4 shows an application of this analysis to the *Sensor Reading Acquisition* business process. Figure 5 shows one example of cross DIO-DSO analysis. The scope of such analysis spans two or more ontologies, including the upper ontology. In this particular case, the analysis determines which ArchiMate *Application Components* perform the acquisition and transformation of the data produced by sensors of the *Drain* type.

4. CONCLUSIONS

This paper proposes using ontologies to integrate multiple domains of enterprise architecture while keeping the models consistent and able to be automatically analysed. The proposal was evaluated with a case study that uses ArchiMate as the upper ontology and a number of domain-specific ontologies that extend the core description language. In this way, the DSOs increase the expressiveness of the upper ontology with domain-specific aspects. This was accom-

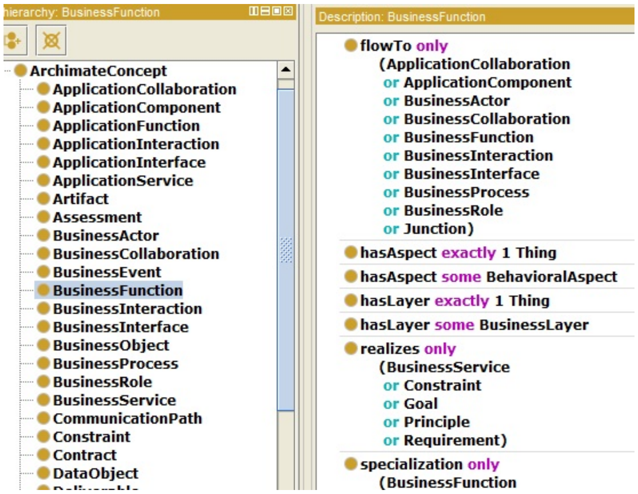

Figure 2: Specification of the ArchiMate meta-model using OWL-DL.

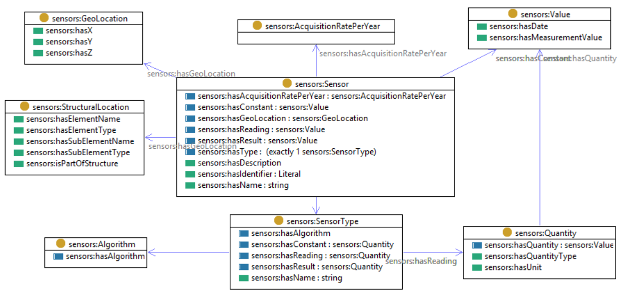

Figure 3: Overview of the sensor domain-specific ontology.

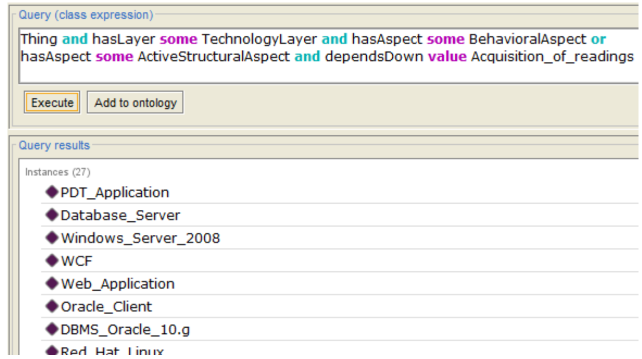

Figure 4: Intra-DIO analysis.

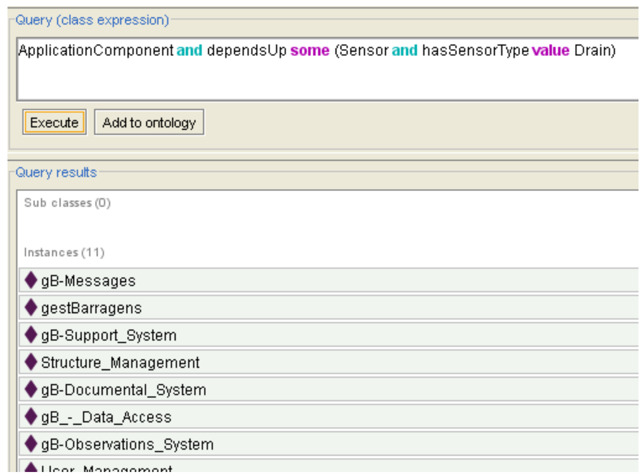

Figure 5: Cross DIO-DSO analysis.

plished by specifying the ArchiMate meta-model as well as each domain-specific language in OWL-DL. The concepts of these ontologies are mapped using integration techniques to prepare the resulting integrated models for analysis.

5. ACKNOWLEDGMENTS

This work was partially supported by the European Commission under the 7th Framework Programme, grant 269940 (http://timbusproject.net/); FCT project PEst-OE/ EEI/ LA0021/ 2013, grant SFRH/ BD/ 69121/ 2010; and COMET K1, FFGl, Austrian Research Promotion Agency.

6. REFERENCES

[1] J. Almeida and G. Guizzardi. An ontological analysis of the notion of community in the rm-odp enterprise language. *Computer Standards & Interfaces*, 35(3):257 – 268, 2013.

[2] C. Azevedo, J. Almeida, M. van Sinderen, D. Quartel, and G. Guizzardi. An ontology-based semantics for the motivation extension to archimate. In *15th IEEE Enterprise Distributed Object Computing Conference*, 2011.

[3] M. Bjekovic, E. Proper, and J.-S. Sottel. Towards a coherent enterprise modelling landscape. In *Sandkuhl, K. (ed.), proceedings of 5th IFIP WG8.1 Working Conference on the Practice of Enterprise Modeling, Rostock*, 2012.

[4] S. Buckl, F. Matthes, and C. M. Schweda. Conceptual models for cross-cutting aspects in enterprise architecture modeling. In *14th IEEE Enterprise Distributed Object Computing Conference*, 2010.

[5] S. Buckl, C. M. Schweda, and F. Matthes. A design theory nexus for situational enterprise architecture management. In *14th IEEE Enterprise Distributed Object Computing Conference*, 2010.

[6] M. A. Bunge. *Treatise on Basic Philosophy Volume 3: Ontology I - The Furniture of the World*. Kluwer Academic Publishers, 1977.

[7] A. Caetano, C. Pereira, and P. Sousa. Generation of business process model views. *Procedia Technology*, 5:378–387, 2012.

[8] M. Galster. Dependencies, traceability and consistency in software architecture: towards a view-based perspective. In *Proceedings of the 5th European Conference on Software Architecture*, 2011.

[9] H. Hoang, J. Jung, and C. Tran. Ontology-based approaches for cross-enterprise collaboration: a literature review on semantic business process management. *Enterprise Information Systems*, pages 1–17, 2013.

[10] ISO/IEC/IEEE. *42010:2011. Systems and Software Engineering: Architecture Description*. ISO, 2011.

[11] E. Kapsammer, T. Reiter, and W. Schwinger. Model-based tool integration - state of the art and future perspectives. In *Proceedings of Conference on Cybernetics and Information Technologies, Systems and Applications*, 2006.

[12] M. Lankhorst. *Enterprise Architecture at Work: Modeling, Communication, and Analysis*. Springer, 2005.

[13] J. Romero, J. I. Jaen, and A. Vallencillo. Realizing correspondences in multi-viewpoint specifications. In *IEEE Enterprise Distributed Object Computing Conference*, 2009.

[14] M. Rosemann, P. Green, and M. Indulska. A reference methodology for conducting ontological analyses. In *23rd Conference on Conceptual Modelling*, 2004.

[15] J. Saat, U. Franke, R. Lagerstrom, and M. Ekstedt. Enterprise architecture meta models for it/business alignment situations. In *14th IEEE Enterprise Distributed Object Computing Conference*, 2010.

[16] G. Wagner. Ontologies and rules for enterprise modeling and simulation. In *15th IEEE Enterprise Distributed Object Computing Conference*, 2011.