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An Ontological Analysis Framework for Domain-Specific Modeling Languages

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ABSTRACT

This article describes how domain-specific modeling languages (DSML) are developed to specifically model certain domains and their phenomena. Over the last 15 years, different kinds of DSMLs have been ontologically analyzed to improve their ontological expressiveness. However, the term 'ontological analyses' encompasses a great variety of different purposes, techniques or methods, and can thus be performed in many different ways without maintaining clear differentiation. Therefore, in this article, the authors aim to structure the process of conducting an ontological analysis, and offers guidelines in the form of descriptive patterns for analyzing a DSML. With the help of this framework, a researcher with a specific purpose can recognize the required patterns and types of methods that can be followed in order to successfully conduct an ontological analysis and achieve the intended purpose.

KEYWORDS

Constructs, Evaluation, Guidelines, Language Improvements, Method, Ontology, Pattern, Process, Purpose, Reference Ontology

1. INTRODUCTION

Domain-specific modeling languages (DSMLs) are developed for creating models within specific domains by means of a strongly cohesive set of domain concepts (Henderson-Sellers, 2012). On the contrary, general-purpose modeling languages (GPML) consist of domain-independent concepts (e.g. UML, EER or BPMN). As a result, DSMLs enable the rapid modeling of the behavior and/or structure of applications in well-defined domains (Sprinkle & Karsai, 2004). Different types of DSMLs have been proposed. Executable DSMLs allow the creation of domain models that can be transformed into executable code. Visual DSMLs on the other hand describe aspects of the physical and social world for purposes of human understanding and communication (Mernik, Heering, & Sloane, 2005). These languages have been developed, for instance, to model different aspects related to economic reality such as the Architecture for Integrated Information Systems (ARIS) framework (Scheer, 1998) and value creation processes (Gailly & Poels, 2007a). In this paper, we will focus on visual DSMLs and henceforth refer to them as DSML.

In order to be effective, a DSML should be sufficiently expressive to represent the domain concepts that are captured by the intended models. To better fulfill these requirements, ontologies have been introduced as a theoretical foundation (Wand, Monarchi, Parsons, & Woo, 1995). For keeping a broad interpretation, we adopt the characterization of ontologies as described by Honderich (2006), which defines ontology as "the set of things whose existence is acknowledged by a particular theory or system of thought". Ontologies support the construction of explicit models of conceptualizations in the form of concrete guidelines for selecting which concepts should be represented as language constructs

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and how they should be applied (Guizzardi, Pires, & Sinderen, 2002). Moreover, ontologies can be applied to evaluate the quality of a modeling language and its ability to describe a certain domain by performing an ontological analysis. An ontological analysis improves a DSML by: (i) providing a rigorous definition of the constructs of a modeling language in terms of real-world semantics, (ii) identifying inappropriately defined constructs, and (iii) recommend language improvements which reduce lack of expressivity, ambiguity, and vagueness (Almeida & Guizzardi, 2013). We refer to the ontology that analyzes a DSML as the reference ontology.

Over the last 15 years, a growing number of DSMLs have been analyzed using different types of reference ontologies. For instance, the integrated process modeling grammar within the ARIS framework has been evaluated using the Bunge Wand Weber (BWW) ontology by Green & Rosemann (2000), or the ArchiMate enterprise architecture language has been evaluated by the Unified Foundational Ontology (UFO) (Azevedo et al., 2015). Other ontological analyses of DSMLs were also performed on, for example, the RM-ODP language (Almeida, Guizzardi, & Santos, 2009) and the REA enterprise modeling language (Geerts & McCarthy, 2003).

Notwithstanding the frequent application of ontologies, the overall process of an ontological analysis remains problematic (Rosemann, Green, & Indulska, 2004), perhaps even more for DSMLs than for GPMLs. While different kinds of techniques exist to analyze a GPML, only a few consider DSMLs. Furthermore, an ontological analysis serves multiple purposes. However, there exists no clear differentiation between these kinds of analyses. Moreover, an ontological analysis can target different aspects of a DSML. For instance, a DSML can be ontologically analyzed by comparing the constructs of the language to an ontology, which can induce changes to its syntax and/or semantics. On the other hand, the domain ontology of a DSML could be analyzed and mapped to a reference ontology, in order to increase the interoperability with, for example, another DSML. Clearly, both such analyses serve an entire different purpose, and require different kinds of means in order to achieve the respective purpose. As such, the term 'ontological analysis' encompasses a great variety of different types of purposes, techniques or methods, and can thus be performed in many different ways, currently without maintaining a clear distinction.

In this paper, we therefore aim to construct a framework that will distinguish the different kinds of ontological analyses that exist. The benefit of this framework will lie in its ability to differentiate between the different purposes for analyzing a DSML, and to determine which aspects of a DSML should be addressed and which kind of method can be implemented, depending on this particular purpose. In other words, we intend to structure the process of conducting an ontological analysis, and offer guidelines when analyzing a DSML. In section 2, we will describe the methodology that is applied in this paper. Section 3 will then formulate the problem definition and the research objectives. In Section 4, we construct our framework as an answer to the problem definition. Section 5 serves as an assessment of our framework and identifies any shortcomings that still exist. Next, section 6 addresses these shortcomings and aims to refine or enhance our framework. In section 7 we then provide a discussion of the framework, its application and discuss any limitations. Finally, in section 8, we present our conclusion and future research.

2. METHODOLOGY

To construct our framework, we adopt the design science methodology of (Gregor & Hevner, 2013) and (Hevner et al., 2004). Their research offers a structured approach to conduct and present design-science research. Gregor and Hevner (2013) differentiate between two main knowledge bases, i.e. descriptive and prescriptive knowledge. Descriptive knowledge is the "what" knowledge about natural phenomena and the laws and regularities among phenomena. The researcher draws appropriately relevant descriptive and propositional knowledge from this base. Prescriptive knowledge is the "how" knowledge of human-built artifacts. This base allows the researcher to examine known artifacts and design theories that have been used to solve the same or similar research problems in the past. Both knowledge bases are investigated for their contributions to the grounding of the research project.