Ontology-Driven Conceptual Modeling with Applications

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Abstract. *This paper provides a short description of a tutorial at the 2008 edition of the Brazilian Symposium on Information Systems (SBSI). The main objective of this tutorial is to introduce students and researchers to the theory and practice of advanced conceptual modeling in general, and domain ontology engineering, in particular, through the application of a new emerging discipline named Ontology-Driven Conceptual Modeling.*

1. Tutorial Short Description

Conceptual Modeling is a discipline of great importance to several areas in Computer Science such as Software and Knowledge Engineering, Enterprise Modeling, Information Systems Design, Database Design, Knowledge Management, among many others. Its main objective is concerned with identifying, analyzing and describing the essential concepts and constraints of a universe of discourse with the help of a (diagrammatic) modeling language that is based on set of basic modeling concepts (forming a metamodel).

In this tutorial we show how conceptual modeling languages can be evaluated and (re) designed with the purpose of improving their *domain appropriateness* and *comprehensibility appropriateness*. In simple terms, *domain appropriateness* is a measure of how truthful the models produced using a modeling language are to the situations in reality they are supposed to represent; *comprehensibility appropriateness* is a measure of how easy is for users of a language to understand, communicate and reason with models produced using that language. As presented in [Guizzardi et al 2005], a suitable conceptual modeling language should be constructed in such a way that its metamodel reflects the structure and semantics of a reference model of the corresponding domain in reality.

What is termed a *Domain Ontology* in Computer Science is a special type of Conceptual Model. In recent years, there has been a growing interest in the development and use of domain ontologies, strongly motivated by the Semantic Web initiative. However, as we showed in [Guizzardi 2006a], an approach for ontology representation uniquely based on the modeling languages adopted in the Semantic Web (e.g., OWL, RDF) is insufficient to address a number of semantic interoperability problems that arise in open and dynamic scenarios (such as, for instance, the Semantic Web itself). In [Guizzardi 2007a], we discussed in depth the difference between *lightweight ontologies* such as the ones produced in the aforementioned languages and *foundational ontologies* i.e., domain-independent philosophically well-founded formal theories. Moreover, we demonstrated that a general conceptual modeling (and ontology representation) language should be constructed in a way that its metamodel reflects the structure and semantics of a properly constructed Foundational Ontology.

In [Guizzardi 2005], we applied the method proposed in [Guizzardi et al 2005] to produce a language designed to meet the desiderata for a general conceptual modeling and ontological engineering language. The reference ontological model used to produce this language is a Foundational Ontology named *UFO (Unified Foundational Ontology)*. UFO addresses issues such as: (i) the general notions of types and their instances; (ii) objects, their intrinsic properties and property-value spaces; (iii) the relation between identity and classification; (iii) distinctions among sorts of types (e.g., kinds, roles, phases, mixins) and their admissible relations; (iv) distinctions among sorts of relational properties; (v) Part-whole relations. This ontology has been developed by adapting and extending a number of theories coming, primarily, from formal ontology in philosophy, but also from philosophical logics, cognitive science and linguistics. The chosen theories are corroborated by thought experiments in philosophy and/or are supported by empirical evidence in cognitive psychology. Furthermore, UFO (and some of its extensions) has been successfully employed in a variety of application scenarios such as Foundations for Distributed Systems [Almeida and Guizzardi 2007], Context-Aware Systems [Dockhorn et al 2006], Software Engineering Environments [Guizzardi et al 2008], IT Governance (ITIL) [Calvi 2007], Rule-Based Systems [Wagner et al 2005, Goedertier et al 2009], Enterprise Modeling [Guizzardi and Wagner 2005a], Service Recommendation [Costa et al 2007], as well as the evaluation, re-design and integration of agent-oriented concepts and methodologies such as TROPOS and AORML [Guizzardi and Guizzardi 2008, Guizzardi et al 2007, Guizzardi 2006b, Guizzardi and Wagner 2005b].

The general conceptual modeling language which is the outcome of this re-design process is a version of UML 2.0. In other words, we have redesigned the UML 2.0 metamodel so that it would: (i) properly represent as modeling primitives the ontological distinctions postulated by UFO; (ii) only accept as grammatically correct models of the language, those that are compatible with the axiomatization of UFO [Guizzardi 2005]. This re-designed metamodel has been implemented in an MDA-based Tool that provides modeling computational support for the proposed language [Benevides 2007]. Since this metamodel incorporates all the axioms postulated by the foundational theory as OCL constraints, the tool can provide automatic capabilities for checking the compliance of the produced models against these axioms.

Besides the proposal of this language, we have advanced a number of additional methodological tools based in UFO. In particular, in the tutorial, we present some *ontological design patterns* that have been used to solve some classical and recurrent problems found in the conceptual modeling and ontological engineering literature [Guarino and Guizzardi 2007] such as the problem of *role modeling with disjoint allowed supertypes* [Guizzardi et al 2004], the problem of *modeling parts of roles* [Guizzardi 2007b], and the problem *of transitivity of part-whole relations* [Guizzardi 2005]. Finally, we show how this ontologically well-founded version of UML can be used to produce conceptually cleaner and semantically unambiguous models in concrete application scenarios such as, for instance, the Electrocardiogram [Nunes et al 2007] and Petroleum domains.

Acknowledgements: A significant part of the material presented in this tutorial has been developed while the author was a member of the EWI Department at the University of Twente in The Netherlands and/or in association with the Laboratory for Applied Ontology (LOA) at the Institute for Cognitive Science and Technology (ISTC-CNR) in Trento, Italy.

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