Ontological Foundations for Conceptual Modeling with Applications

Giancarlo Guizzardi

Ontology and Conceptual Modeling Research Group (NEMO)
Computer Science Department,
Federal University of Espírito Santo (UFES), Brazil
gguizzardi@inf.ufes.br

Abstract. The main objective of this tutorial is to introduce researchers to the theory and practice of advanced conceptual modeling through the application of a new emerging discipline named Ontology-Driven Conceptual Modeling. In this discipline, theories coming from areas such as Formal Ontology in philosophy, but also Cognitve Science, Philosophical Logics and Linguistics are employed to derive engineering tools (e.g., modeling languages, methodologies, design patterns, model compilers and simulators) for improving the theory and practice of Conceptual Modeling. In particular, here, the expressiveness and relevance of these theories and derived tools are demonstrated through their application to solve some classical and recurrent conceptual modeling problems concerning the well-founded representation of: classification and taxonomic structures, part-whole relations, intrinsic and relational properties, formal and material associations, association specialization, attribute value spaces and roles.

Keywords: Ontological Foundations, Ontology-Driven Conceptual Modeling, Unified Foundational Ontology (UFO), OntoUML.

1 Introduction

The main objective of this tutorial is to introduce researchers to the theory and practice of advanced conceptual modeling through the application of a new emerging discipline named Ontology-Driven Conceptual Modeling.

Conceptual Modeling is a discipline of great importance to several areas in Computer Science. 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 a 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 *Ontological Adequacy*.

In simple terms, Ontological Adequacy is a measure of how truthful the models produced using a modeling language are to the situations in the reality they are supposed to represent (*Domain Appropriateness*), and how easy it is for users to use these models for communicating, domain learning and problem-solving (*Comprehensibility Appropriateness*) [1].

The tutorial starts by briefly discussing a systematic evaluation method for comparing a metamodel of the concepts underlying a language to a *Reference Ontology* of the corresponding domain in reality. The in this presentation is on general conceptual modeling languages (as opposed to domain specific ones). Hence, the reference ontology employed here is a Foundational (or Upper-level) Ontology. Moreover, since, the tutorial focuses on structural modeling aspects (as opposed to dynamic ones), this foundational ontology is an *Ontology of Endurants* addressing issues such as categories of object types and taxonomic structures, intrinsic properties, modes and attribute value spaces, formal and material relations, association specialization, as well as different and subtle aspects regarding the representation of conceptual part-whole relations.

The foundational ontology which is adopted in this tutorial (termed *UFO – Unified Foundational Ontology*) has been developed by adapting and extending a number of theories coming, primarily, from formal ontology in philosophy, but also from cognitive science, philosophical logics and linguistics. Once developed, every sub- theory of the ontology has been used for the creation of a number of methodological tools including: (a) an ontologically well-founded version of UML 2.0 (latter dubbed *OntoUML*) with an explicitly defined metamodel, an expressive formal characterization and a number of associated methodological guidelines; (b) a set of Ontological Design Patterns, including Model Construction Patterns, Model Analysis Patterns and Model Transformation Patterns; (c) Computational Tools for Model Creation and Verification, but also Model Validation via Visual Simulation.

The expressiveness and relevance of these engineering tools are shown throughout the presentation to solve some classical and recurrent conceptual modeling problems. In particular, the tutorial discusses a number of examples of the successful application of these tools in complex domains and industrial application scenarios.

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