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# Linked Open Models: Extending Linked Open Data with conceptual model information

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ABSTRACT

As the uptake of the Semantic Web vision has been relatively slow, a strategy based on pragmatic steps is being deployed in order to setup enablers and to stimulate acceptance. "Linked Open Data" refers to one of these early steps, benefiting from an available technological space (RDF, HTTP). The paper proposes "Linked Open Models" as a possible additional step, whose aim is to enable users to externalize knowledge in the form of diagrammatic models – a type of content that is human-readable, as well as linkable in the way promoted by the Linked Data paradigm. Consequently, diagrams become user-generated content that semantically enriches Linked Data, thus allowing richer constraints or connections in queries. The vision emerged from the context and use cases provided by the ComVantage FP7 research project, where linking benefits for conceptual diagrammatic models have been investigated. However the paper also discusses the vision's degree of generality, beyond the scope of the exemplary project use cases. Feasibility was demonstrated with a vocabulary and a prototype mechanism for exposing the models created with a hybrid, domain-specific modeling method in a Linked Data-driven collaboration environment.



## 1. Introduction

The slow adoption of the Semantic Web vision [1] has motivated researchers in defining and setting up concepts or technologies acting as enablers and facilitators, focused on pragmatic solutions and rooted in available technology, necessary to support a gradual advancement over the gap between the current state of affairs and the vision. While research results from artificial intelligence and ontology engineering are available as proof-of-concepts for the far end of the vision, it became obvious that the building blocks on which the Web 2.0 was developed (e.g., AJAX, XML/JSON, content management systems) were lacking certain ingredients required by the Semantic Web vision.

The Linked Data paradigm [2] emerged as such an intermediate step, with the aim of establishing both an instance data test-bed and an enabling environment for the future Semantic Web. The paradigm reduces the role of "ontologies" to the function of inducing structure to Linked Datasets (as "vocabularies"), and this is also how the term "ontology" will be used throughout this paper (unless indicated otherwise). With Linked Data, emphasis is placed on structuring, distributing and querying data in ways that are inspired by the "semantic networks" approach from artificial intelligence, grafted on the networked nature of the Web. The paradigm aims to induce a network effect to data linking, not unlike the one that enabled the growth of Web 1.0 (based on document

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linking) or Web 2.0 (based on social and content linking). We extend this view with an additional layer – "Linked Models" – by employing Linked Data principles and techniques for content of different nature and granularity – *conceptual (diagrammatic) models*.

The Linked Data paradigm aims to educate the Web developers towards new practices for information structuring, with an impact comparable to the one that made possible the rise of the relational databases. Indeed, "thinking in tables" had the advantage of being well defined at formalism level (relational algebra), well promoted by tools and well assimilated (on the presentation layer) by the end-users who produce content (data). Filling up, sorting, filtering tables is not anymore a matter of technical skills, it is an intuitive way in which most users expect to interact with their data records, regardless of purpose. A possible analogy, intended to bring the argument closer to the work at hand, relies on a statement made in the panel discussions of the Open Model Initiative workshop of 2012 by John Mylopoulos: "…[in the future] conceptual modeling will be taught in the elementary school" [3]. The statement assumes a level of education and tool support that enables end-users to structure knowledge without feeling that they're actually making a content structuring effort. It is a motivational assumption for the work at hand that such enablers may come from the field of conceptual modeling.

The goal of this paper is to communicate the vision of "Linked Open Models", with an instantiation in the case of the ComVantage EU research project [4], where models are exported using an RDF [5] vocabulary in order to facilitate inter-model linking, model-to-data linking, model transformation and sharing. The paper is structured as follows: Section 2 states the problem and positions its research goals relative to the context of the ComVantage research project. Section 3 describes a minimal but representative running example, detailing the mechanism of exposing diagrammatic conceptual models as Linked Data. Section 4 analyses both foreseen and confirmed benefits on some exemplary cases, and continues with a discussion on the level of generality and reusability beyond the project context. Section 5 indicates related works. The paper concludes with a contribution summary against the baseline given by the related works, provides a SWOT evaluation based on the existing proof-of-concept and formulates the final takeaway messages.

## 2. Problem context and statement

### 2.1. Motivation

Modeling languages are commonly involved in model-driven software engineering or automated programming [6], as "means to an end", typically aiming for code generation. We, through the Open Model Initiative [7], advocate a broader scope for conceptual modeling, as means of *knowledge externalization/representation* for the purpose of communication and understanding [8]. For example, the practice of Business Process Modeling has developed in time as a successful decision support or knowledge management approach [9,10] even without the benefit of workflow automation. Machine-readability is just a particular type of "understanding" and, in this respect, the work at hand enables model understanding and sharing within a Linked Open Data environment, with the potential of enabling *diagram-awareness* in information systems at run-time (a possible generalization of the process-awareness concept [11]).

Just as Web 2.0 enabled user content production through simple forms and templates provided by content management systems, the work at hand promotes diagrammatic conceptual modeling as a way of inducing richer structure and semantics for Linked Data in a user-oriented way, for those who are agnostic of ontology engineering but are familiar with diagrammatic modeling. The challenge of knowledge acquisition for the Semantic Web can thus be met on a more domain-focused level (compared to generic ontology editors like Protégé [12]), possibly sacrificing inference capabilities (or rather compensating them with query-time model transformations, as a use case will later suggest).

We add to the motivation the research challenges stated in the FInES Roadmap [13]. FInES is a research community and project cluster focused on investigating the potential of enterprise systems that will leverage the benefits of the "Future Internet". A particular subset of their research challenges are grouped in the so-called *Knowledge Dimension*: *RC1. The Unified Digital Enterprise; RC2. Linked Open Knowledge; RC3. Complex Systems Modeling.* Conceptual modeling can have significant impact in advancing this dimension, and the Linked Open Models vision discussed in this paper is a pragmatic proposal in this respect, just as Linked Open Data is a pragmatic enabler for the Semantic Web. In relation to the FInES challenges, modeling languages can provide an entry point to the *Linked Open Knowledge* and linking capabilities are required to glue together the digital image of the enterprise across different types of models.

### 2.2. Framework

The work at hand relies on (a) *methodological enablers*: the metamodeling framework of the Open Model Initiative Laboratory [7] and the notion of "modeling method" as defined in [14]; (b) *technological enablers*: a metamodeling platform (ADOxx® [15]) on which such a method can be implemented in the form of a modeling tool, as well as the technological space of the Linked Data paradigm employed for model serialization.

According to [14], a *modeling method* comprises the following building blocks:

(1) A *modeling language* describes the set of modeling constructs, including their custom notation (how they look), grammar (how they can be visually connected) and semantics (property sets and relations prescribed by a metamodel). The modeling language can be partitioned in *model types* addressing different facets or abstraction layers of the system under study. This partitioning can be a usability feature (a top-down decomposition approach to avoid visual cluttering in diagrams) or a