Modular Ontologies as a Bridge Between Human Conceptualization and Data

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Abstract. Ontologies can be viewed as the middle layer between pure human conceptualization and machine readability. However, they have not lived up to their promises so far. Most ontologies are too tailored to specific data and use-cases. By making sometimes strong, or sometimes too weak, ontological commitments, many existing ontologies do not adequatly reflect human conceptualizations. As a result, sharing and reuse of ontologies is greatly inhibited. In order to more effectively preserve this notion of human conceptualization, an ontology should be designed with modularity and extensibility in mind. A modular ontology thus may act as a bridge between human conceptualization and data.

1 The Case for Modular Ontologies

The Internet is the single largest repository of knowledge to have ever existed and continues to grow every second. The amount of data continuously generated by both humans and machines defies comprehension: from second-by-second meteorological data gathered by sensors to academic articles written by scientists to communications on social media networks to collaborative articles on Wikipedia. How can we represent and link these disparate forms of data together in order to generate an understandable gestalt? We would require a way to organize acquired data such that some critical part of the human conceptualization of each piece is preserved.

Ontologies, as "explicit specifications of conceptualizations," seem like a natural fit for the role [2]. With the explosive growth of the Semantic Web in the last decade, it would seem that they have seen no small success for that purpose. Ontologies offer a human accessible organization of immense amounts of data and act as a vehicle for the sharing and reuse of knowledge.

Unfortunately, published ontologies have often not lived up to these promises. Large, monolithic ontologies, designed with very strong – or very weak – ontological commitments are very difficult to reuse across the same domain, let alone different domains. Strong ontological commitments lead to overspecification, to ontologies essentially being only fit for the singular purpose for which they were originally designed. Weak ones lead to ambiguity of the model, sometimes to the extent that is hard to grasp what is actually being modeled.

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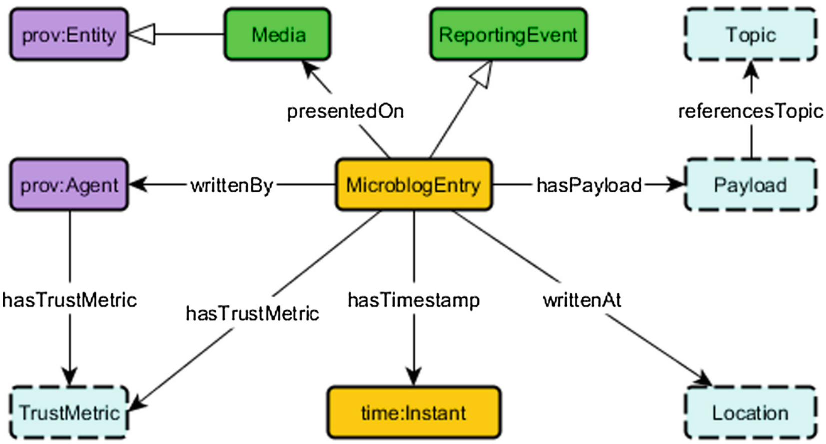

Fig. 1. This is a graphical view of the MicroblogEntry ODP [12]. Yellow boxes indicate datatypes, light blue boxes with dashed borders indicate external patterns. Purple is used for external classes belonging to PROV-O [1]. Green is used for external classes belonging to [8]. White arrowheads represent the owl:SubclassOf relation. (Color figure online)

We posit that one effective way to obtain ontologies which are easier to reuse, is to build them in a modular fashion. A sufficiently modularized ontology [9] is designed such that individual users can easily adapt an ontology to their use cases, while maintaining integration and relationships with other versions of the ontology. A modular ontology is constructed by piecing together so-called ontology modules. Ontology modules are created by adapting Ontology Design Patterns to the domain and use-case [4,5].

2 Ontology Design Patterns

In general, patterns are invariances that may be observed over different media (e.g. data or processes). Ontology Design Patterns (ODP) are the recognition of *conceptual* patterns that occur across different domains. Modeling with ODPs has established itself as an ontology engineering paradigm [5].

The Semantic Trajectory ODP [7] is a classic example of a recurring pattern. However, patterns are designed to be sufficiently general as to apply to many different cases as possible. Thus, it is necessary to create a module from them by adapting the pattern to the specific domain and use-case in mind. The Semantic Trajectory ODP has been successfully modularized a number of times; two prominent examples are the CruiseTrajectory ODP [11] and the SpatiotemporalExtent ODP [10]. For a thorough tutorial on creating modules out of patterns, see [9].

As another example, Fig. 1 shows a graphical representation of the MicroblogEntry ODP [12]. This ODP clearly demonstrates pattern reuse and how adequate ontological commitment eases of modularization. This ODP was engineered to leverage as much existing work as possible. For example, the Media and ReportingEvent concepts are defined in [8]. The concepts Entity and Agent come from the popular PROV Ontology that express provenance data [1]. Further, this ODP avoids overly strong ontological commitments, allowing it to be easily modularized to represent specific microblogs (e.g. Twitter vs. Facebook vs. Instagram).

3 The Future of Modular Ontology Engineering

The promise of modular ontologies is still being realized. There are yet open questions concerning ontology design patterns, their usage, and the surrounding supporting tools and infrastructure. For a more thorough examination of these questions and challenges, see [3]. That is not to say that there are no efforts underway; here, we briefly identify some of these ongoing efforts.

Perhaps the most fundamental purpose of the Semantic Web is to enable the sharing and reuse of knowledge. Certainly, a pattern is knowledge in and of itself. Thus, it is only reasonable that there needs to be a way to enable the sharing and reuse of patterns, as well. To do so, we are working towards the development of a "smart," central repository. Such a repository would be initially populated with a critical mass of fundamental ODPs. That is, a collection of ODPs with sufficient breadth and generalization such that their combination covers any complex conceptualization.

In addition, these patterns will be annotated in a systematic and rigorous way. Answering questions such as

- How do patterns interact with each other?
- Do they import other patterns?
- Which pattern did this module reuse as a template?

Recently, [6] introduced the Ontology Design Pattern Representation Language (OPLa) as a way to address those questions, and others. The smart repository would use these OPLa annotations in order to inform an ontology engineer on available patterns, especially those related to their domain and use-cases.

Between the central repository and OPLa, the next step will be to create a graphical interface for the assembly and modularization of ontologies. This will be a combination of different visualization strategies and a plug-and-play system for ODPs.

And finally, as we learn how to most help humans create ontologies, can we attempt to also automate these processes? That is, automatically create an ontology from a dataset and present it as a "first draft" to the ontology engineer for editing?

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