Towards a Graphical Notation for OWL 2

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Abstract. The Ontology Definition Metamodel (ODM) defines a set of UML metamodels and profiles for development of RDF and OWL. The UML profiles in the ODM specification adapt UML notations to provide a form of visual representation for RDF and OWL. Recently, the ODM Revision Task Force (RTF) has been focused on addressing remaining open issues and usability concerns that have arisen as implementations mature. Critical issues include the development of adequate notations to distinguish necessary from necessary and sufficient conditions for class descriptions, representation of properties and individuals, and more general support for literals. While these may seem simple, it remains challenging to find solutions that result in well-formed and usable UML models with equivalent semantics in OWL. The ODM RTF is considering solutions to these and further issues including compatibility with OWL 2. This paper describes some of the revised approaches, and presents potential extensions to the UML profile to address requirements of OWL 2.

Background and Motivation

The Object Management Group (OMG) Ontology Definition Metamodel (ODM) standard was adopted in 2006, finalized in 2008, and is set to become an ISO standard in the coming year [1]. It includes a family of metamodels (models of the abstract syntax) for the Resource Description Framework [2], the Web Ontology Language [3], ISO Common Logic [4], ISO Topic Maps [5], and several UML (Unified Modeling Language [6]) profiles to enable use of UML tools for RDF vocabulary, OWL ontology, and topic map development. It also contains mappings (some partial and some complete) to support model transformations from one representation paradigm to another. It bridges standards and best practices from several communities and provides a foundation for defining, developing, and managing information models as independent but equal components of larger systems.

This paper describes (1) the structure of the UML profiles for RDF and OWL, (2) salient features of the UML-based graphical notations included in these profiles, (3)

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current approaches to some of the more challenging open issues, (4) early thinking on extensions required for OWL 2, (5) other current activities and future directions, and (6) conclusions with respect to the efficacy of the approach.

A key goal driving development of the UML notations was to enable ontology-based information models to be integral parts of an information-centric system architecture. Benefits of an information-centric architectural approach, incorporating coherent and integrated sets of vocabularies, ontologies, and "gold standard" data models, developed and maintained separately from other aspects of a system such as process and service architectures, include:

- Increased platform independence as well as interoperability across services, processes, and other applications
- Limited breakage and rework as applications and services evolve, reducing maintenance costs
- Improved software, process, and service quality (through shared information services, vocabularies, and other artifacts that are logically consistent – internally and with one another)
- Opportunity for new capabilities and increasing automation in search, complex event and other transactional processing, transformation services, adaptive and predictive capabilities, etc.

Additional motivation for a UML-based visual notation for ontology development was to provide a standard graphical notation to enhance communication of OWL to others. This in turn should make the ontologies understandable by a much larger audience who are more versed in traditional information or software modeling. UML is widely supported by the software engineering community with a variety of mature, open source and commercial tools. The UML diagrams resonate well with our audience of RDF and OWL developers and with those seeking to incorporate these models in larger architectures as described above, including further roles of these models as described in [7].

Recently, the ODM Revision Task Force (RTF) has been focused on addressing remaining open issues and usability concerns. Critical issues include an adequate notation to distinguish necessary from necessary and sufficient conditions for class descriptions, property representation, representation of individuals, and more general approaches to support literals. The RTF is also following OWL 2 development closely [8], to ensure that the ODM 1.1 revision will be compatible with the changes to the OWL language to the extent possible, with a clear path for migration.

Structure of the UML Profiles for RDF and OWL

The UML profiles are defined in compliance with the Profiles section of the UML Superstructure Specification [6]. They are designed to support modelers developing vocabularies in RDF and richer ontologies in the Web Ontology Language (OWL) through reuse of UML notations and use of standard UML tools.

Profiles adapt both the notations of UML and their underlying modeling elements to tailor the language for the needs of specific modeling domains. They package the elements available in a particular profile and provide lightweight extensions to the UML elements included in the profile. The principal extension mechanism is the *stereotype,* which defines a restricted usage of an existing element and may also add custom properties unique to that usage. In UML diagrams, an application of a stereotype is indicated by one or more stereotype keywords enclosed in guillemet characters (e.g., «owlClass»), which are shown as part of the normal diagram symbol.

The UML profiles for RDF and OWL are intended to be intuitive for UML users, and to:

- Reuse existing UML constructs directly when they have the same semantics as RDF and OWL
- Define customized stereotypes of existing UML constructs to make them consistent with RDF and OWL semantics
- When suitable UML constructs do not already exist, define additional combinations of stereotyped UML constructs to provide usable forms of notation for RDF and OWL semantics
- Utilize a model library (provided in Annex A of the ODM specification) to refer to defined sets of foundation elements (such as standard data types and property values)

The UML Profile for RDF provides a basic set of constructs to support users who wish to restrict their vocabularies to RDF/S, and to reflect the structure of the RDF and OWL languages to the extent possible. All constructs of the RDF profile are included in the profile for OWL, which defines the additional constructs needed for development of ontologies in OWL.

Critical features that provide hooks for linking models to the Web, such as definitions for RDF documents, Uniform Resource Identifiers (URIs/IRIs), namespace definitions, and so forth are included in the RDF profile package. They are isolated from the other definitions in a manner consistent with the OWL 2 Structural Specification [9] and could be moved to an independent package to facilitate alignment with OWL 2.

UML Profile Notations for RDF and OWL

Much of the RDF profile is fairly straightforward – RDF classes are represented by stereotyped UML classes, RDF datatypes are represented by stereotyped UML datatypes, and so forth. Key features of the RDF profile worth mentioning include:

- `rdfs:Resource` is modeled as UML::InstanceSpecification
- `rdf:Property` is modeled by a combination of UML::Property, UML::Association, and UML::AssociationClass
- Graphs, named graphs (per [10]), and documents are all modeled as UML::Package

Figure 1 provides an example depicting a property definition (using the AssociationClass notation).

Figure 1. Example RDF Property Definition, AssociationClass Notation

The profile moves away from the comfort zone of most UML modelers in its representation of restrictions. Figure 2 shows a notional set of relationships from a fictional brokerage ontology describing bonds and bond positions. The example includes OWL classes and object properties, restrictions, and the latest RTF approach to depict necessary vs. necessary and sufficient conditions for class membership. A fragment of the RDF/XML serialization for OWL is given in Figure 3.

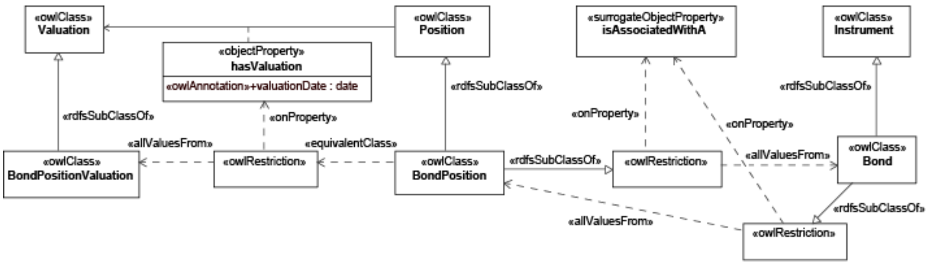

Figure 2. Basic Stereotypes for OWL Classes, Properties, and Restrictions

```
<owl:Class rdf:about="Bond">
    <rdfs:subClassOf rdf:resource="Instrument"/>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="isAssociatedWithA"/>
            <owl:allValuesFrom rdf:resource="BondPosition"/>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:about="BondPosition">
    <owl:equivalentClass>
        <owl:Restriction>
            <owl:onProperty rdf:resource="hasValuation"/>
            <owl:allValuesFrom rdf:resource="BondPositionValuation"/>
        </owl:Restriction>
    </owl:equivalentClass>
    <rdfs:subClassOf rdf:resource="Position"/>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="isAssociatedWithA"/>
            <owl:allValuesFrom rdf:resource="Bond"/>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:about="BondPositionValuation">
    <rdfs:subClassOf rdf:resource="Valuation"/>
<owl:Class rdf:about="Instrument"/>
<owl:ObjectProperty rdf:about="isAssociatedWithA">
    <rdfs:domain>
        <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
                <owl:Class rdf:about="Instrument"/>
                <owl:Class rdf:about="Position"/>
            </owl:unionOf>
        </owl:Class>
```

```
        </rdfs:domain>
        <rdfs:range>
            <owl:Class>
                <owl:unionOf rdf:parseType="Collection">
                    <owl:Class rdf:about="Instrument"/>
                    <owl:Class rdf:about="Position"/>
                </owl:unionOf>
            </owl:Class>
        </rdfs:range>
    </owl:ObjectProperty>
```

Figure 3. OWL Fragment for Figure 2 (partial)

Figures 4 and 5 provide an early view of the RTF thinking with respect to the use of surrogates that stereotype UML classes as an additional form for property notation. These surrogate classes would allow standalone property modeling (i.e., without dragging the domain and range of a property onto all diagrams). A default domain and range of `owl:Thing` would be required by UML model checkers, but could be suppressed in any transformation to OWL, as desired.

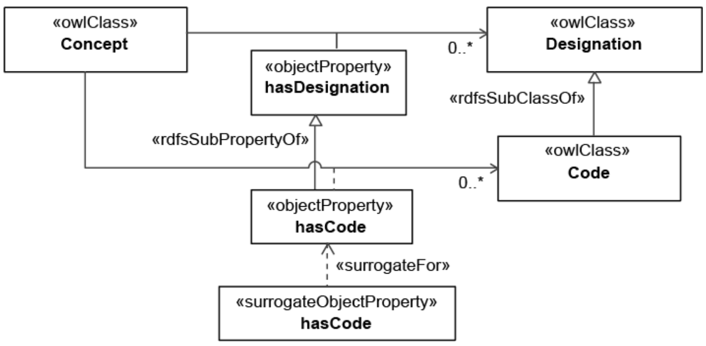

Figure 4. Primary and Surrogate OWL Object Property Notation

As shown in Figure 5, the surrogate property could then be used as a standalone entity in other diagrams, in particular for depiction of property hierarchies, in complex restrictions, and so forth. Relationships defined on the surrogates would be merged with the primary definitions for those properties in any generated OWL.

Additional work is needed to validate these additions from a usability perspective and to ensure compatibility with multiple UML tools. Having said this, the task force is "closing in" on this approach from a UML language viewpoint (i.e., the strategy reflects valid UML), providing a clear and consistent notation that ontologists can use for development purposes. The RTF is also investigating the impact of this approach on UML representation of individuals, in particular for relationships between individuals that are defined through restrictions (rather than domain/range relations).

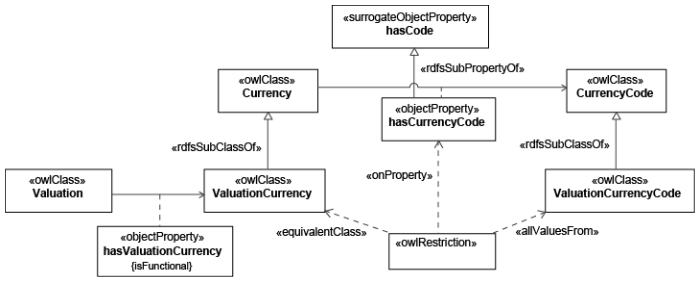

Figure 5. Use of Surrogate Property Notation

Extending the UML Profiles to Support OWL 2

Several features of OWL 2 will assist in simplifying or improving the current metamodel and profile for OWL. Ontology property and annotation representation is more consistent in OWL 2, and will be easier to support. An abstract stereotype for Entity will provide a common "hook" for annotation properties such as version information, which must be duplicated on all stereotypes where appropriate at present. Individual representation, which the task force has been struggling with to date, is facilitated by changes in OWL 2 as well. Other features, such as notation for declarations (possibly in the form of a tagged value), and property chains, require additional prototyping. Figure 6 provides an example of the latest approach to representation of disjoint unions which leverages existing UML::GeneralizationSet notation. A number of the stereotypes shown, including «unionOf», «disjointUnionOf», and «unionClass» are optional from a language mapping perspective but provide visual cues to aid in communication. Limiting the need to display anonymous classes, without loss of information, is also under consideration.

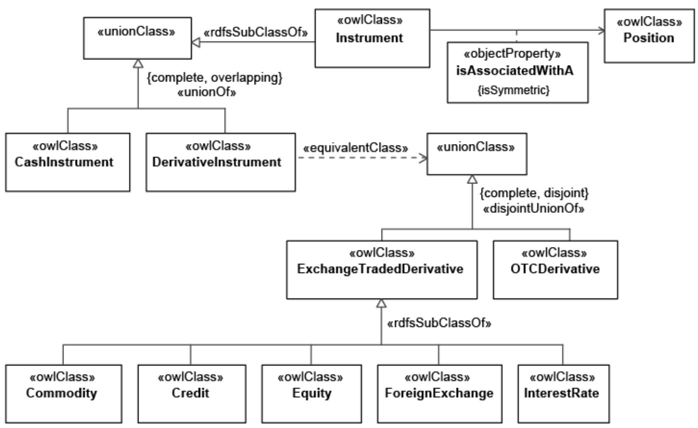

Figure 6. Graphical Notation for Disjoint Union (Proposed)

The RTF is committed to development of a preliminary notation for OWL 2 before completion of the ODM 1.1 RTF report, to facilitate migration and avoid downstream breakage in the ODM 1.1 revision.

Current and Future Directions

In addition to the work identified above (including support for OWL 2), there are ongoing efforts at OMG to develop mappings from the ODM to other specifications, including:

- The forthcoming Information Management Metamodel [11] – to IMM metamodels for XML Schema and Entity-Relationship diagramming
- The recent SoaML specification [12] for Service Oriented Architectures (where extensions under consideration include an ODM-based ontology for OMG business process representations, i.e., a next-generation OWL-S/WSMO ontology [13])
- The Production Rule Representation (PRR) specification [14], related to the Rule Interchange Format [15] work at W3C
- OMG and ISO standards for systems engineering and product data modeling, including SysML [16] and ISO STEP [17]

The fact that there is significant interest from a growing community at OMG for these mappings is evidence that the semantics are becoming increasingly important in many aspects of software and systems engineering.

Conclusion

While more work remains to be done before the UML profiles for RDF and OWL become widely available and in common use, there is a growing, active community interested in seeing this happen, both within OMG and from outside groups. OMG members and non-members can participate in further specification development, related mapping work, and new ideas for building on this early foundation. We welcome feedback on the current and future versions of ODM, as well as implementers willing to tackle tool and applications development. Several open source projects have been initiated, most notably at the Eclipse foundation, where a new ODM initiative will be launched later this year as a part of the Eclipse Modeling Foundation (EMF) Model Development Tools (MDT) subproject.

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