Formal Ontologies in Model-based Software Development

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About

In general, ontologies as formal models are used in MBSD for formal representation of

- domain knowledge (i.e. domain models) and
- requirements of a system.

In our approach, in addition to the above

- the **system ontology** of a MBSD tool (i.e. CoCoViLa)
- and **links to external software artefacts** available on the web or made available by other MBSD tools are used.
Introducing ontologies into software development process supported by CoCoViLa

Domain ontology development phases

- Acquisition of domain knowledge
- Specification (goal, scope, requirements, etc)
- Conceptualization
- Formalization of conceptualization and implementation (RDF/OWL)
- Testing

DSL development phases

- Domain analysis (inc. requirements)
- Design (the DSL meta-model ontology and other related concepts)
- Implementation (the DSL design templates, links to meta-model ontology, Java classes, etc)
- Deployment (using the DSL for application development)
- Testing and maintenance

Laulasmaa, 21.09.2015
The DSL meta-model ontology

- The **DSL meta-model ontology** is a formal ontology that links together the system ontology and one or more domain ontologies as well as may include links to external software artefacts on the Web.

- The **system ontology** defines a set of system-specific concepts of the MBSD system (or tool) and relationships among them.

- The **domain ontology** provides a specification of a conceptualization of a domain.
The concept of DSL meta-model ontology
A fragment of the CoCoViLa system ontology

The current version of this ontology includes OWL descriptions of 40 classes, 21 object properties and 16 data properties.

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Automated generation of concept specification templates from domain ontology

Automatically generated according to the given set of transformation rules [2]

Templates for the OWL class Rectangle and its super-classes.

```java
specifierion GeometricShape {  
    double Area;  }

specifierion _2DimShape super GeometricShape {  
    double Perimeter;  }

specifierion Rectangle super _2DimShape {  
    double Height, Width, Diagonal;  }
```
Mapping domain ontology to the CoCoViLa language

OWL constructs for object property characteristics, property restrictions and complex classes cannot be mapped to the CoCoViLa modelling language [2].
Mapping ...

- For each (or selected) domain ontology class in the DSL meta-model ontology a corresponding instance of the `ConceptSpecificationTemplate` class (from the system ontology) is created and linked to it via the `isGeneratedFrom` object property value.

- This object property value indicates from what domain ontology class the template is automatically generated.

- All this can be automated.
An Example: the Geometry DSL Meta-model Ontology (a fragment)

For DSL designer:

1. Import system ontology („sys“) and domain ontology („geo“) to the DSL meta-model ontology („meta“).

2. Some individuals and links are created automatically.

3. Create additional individuals and their relationships.

```
SubClassOf( sys:MetaClass sys:JavaClass )
SubClassOf( sys:VisualClass sys:MetaClass )
DataPropertyDomain( sys:hasIcon sys:VisualClass )
DataPropertyRange( sys:hasIcon xsd:anyURI )
SubClassOf( geo:Rectangle geo:2DimShape )

 Individuals and their relationships

ClassAssertion( sys:ConceptSpecificationTemplate meta:CST1 )
ClassAssertion( sys:ConceptSpecification meta:CS1 )
ClassAssertion( sys:VisualClass meta:VC1 )
ClassAssertion( geo:Rectangle meta:Rectangle )

ObjectPropertyAssertion( sys:isGeneratedFrom meta:CST1 meta:Rectangle )
ObjectPropertyAssertion( sys:hasTemplate meta:CS1 meta:CST1 )
ObjectPropertyAssertion( sys:implements meta:VC1 meta:CS1 )
DataPropertyAssertion( sys:hasIcon meta:VC1
```
The architecture of the CoCoViLa extension
Implementation details

- Contact Andres!
Benefits

- It is easy to incorporate the domain terminology into the DSL at the early development stages due to formalization of domain ontology.
- Separation of different kinds of knowledge about the system, domain and a DSL into modular OWL ontologies makes the knowledge more reusable.
- Automatic generation of design templates of the DSL meta-model.
- Linking the DSL meta-model ontology components with external resources over the Web.
- Capturing the evolution of a domain in the DSL via automated transformations [2].
- Using the DSL meta-model ontology makes it possible to automatically check its consistency using DL reasoning facilities used for debugging DSL meta-models.
- The system ontology is always related to the running version of the system. Creation of the system documentation on the basis of the system ontology guarantees that documentation is up-to-date and consistent with the system.
Limitations

- Problems of creation of formal domain ontologies as ontology engineering techniques do not constitute a part of existing traditional software development methodologies. This may create initial complexity.

- For semantic integration of artefacts from external tools and models, the approach requires the commitment to a common system ontology or availability of system ontologies of these tools.
Conclusion

- Representing domain models and the system model as OWL ontologies and linking them together to form a unified DSL meta-model ontology makes it possible to effectively integrate software artefacts that constitute a DSL meta-model as well as link it with external resources over the Web.

- This facilitates dynamic loading (instantiation) of software artefacts of DSL meta-models to a DSL development tool.

- We have prototypically implemented our approach as an extension to the CoCoViLa DSL modelling tool.
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References


Thank you!