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# Knowledge Representation and Mapping for Collaborative in Manufacturing Supply Chain Based on OWL and UML

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**Abstract:** Through the comparison analysis of the similarity between UML and OWL based on the OWL syntax elements with reference to OWL Full language, the OWL structure could be described with existing UML language through the direct mapping and the extended mapping. So, the mapping of ontology model between OWL and UML could be realized and the automatic conversion could be processed by the extensible stylesheet language transformation. Further, this study proposed a UML model of collaborative members in manufacturing supply chain and generated the corresponding ontology model by the mapping conversion; with the help of Pellet and Protégé the syntax check and reasoning and validation were tested. The study shows that the method of automatic conversion from the UML class diagram to the OWL file that was proposed in this study is feasible and the result is accurate. In the field of ontology modeling, by the rich expression function of object-oriented graphics in UML model, the combination of UML language and OWL language with their advantages could effectively develop the ontology for the semantic web.

**Key words:** Knowledge representation, mapping, collaborative, OWL, UML

## INTRODUCTION

Unified Modeling Language (UML) is widely applied in the software design and other industry modeling fields because of the powerful object-oriented graph expression function. In addition, the UML language for modeling analysis of web services is relatively successful. The combination of UML language and OWL language with their advantages could effectively develop the ontology for the semantic web; but how to use UML language for description of semantic web and knowledge representation is an important issue to be resolved.

## MAPPING RULES BETWEEN UML AND OWL

UML is a kind of description languages for system modeling rather than a kind of modeling methods and it can't replace any kind of already existing, or perhaps a new modeling method. Due to the definition of the UML does not adopt strict and complete formal technology, this graphical modeling language would often cause semantic fuzziness which affects the efficiency of modeling (Peng *et al*., 2006; Teng and Wan, 2005). For the problem that UML cannot be used as a formal language of requirement description, Wang *et al*. (2008) had a study in comparative analysis of the similarities and differences between object-oriented modeling and ontology modeling and ontology technology was proposed to make up for the defects existing in the UML specification.

Through the analysis of the each other's definitions of ontology and UML, there is reliable overlap and association in part. At the same time, UML provides an extension mechanism that could refine the standard semantic by the rigorous additional ways (Zhong and Chen, 2006). The extension mechanism of UML contains the stereotype, constraints, annotation and tag values. The stereotype is used to classify the model elements or make a signs and it is created on the basis of the standard UML element. The object of the standard UML element and its stereotype would be a new UML element and have a new semantics. As a result, the inheritance relationship of ontology is accurate formal expressed in UML. Therefore, by means of ontology to represent the UML concepts and their relationships (Berardi *et al*., 2005), the UML could describe the domain knowledge more fully.

This study considers that by the analysis of the similarity between UML and OWL based on the OWL syntax elements with reference to OWL Full language, the OWL structure could be described with existing UML language through the direct mapping and the extended mapping. So, the mapping of ontology model between OWL and UML could be realized. Table 1 gives

Table 1: Part of mapping rules between OWL and UML

| No. | OWL-Full* | UML** | Notes |
|---|---|---|---|
| 1 | Class (thing, nothing) | Class | |
| 2 | rdfs: sub class of | Generalization between classes | |
| 3 | rdf:Property | OwnedAttribute, binary association | Aspects of Attributes and Associations and Classes |
| 4 | rdfs:subPropertyOf | Generalization between Associations | <subPropertyOf> |
| 5 | rdfs:domain | Association; Attribute (source class of an association) | <domain> |
| 6 | rdfs:range | Association (target class of an association) | <range> |
| 7 | Individual | Instance; (Class; Association) | <individual>; <individualOf>;<typeOf> |

*: OWL Web Ontology Language Semantics and Abstract Syntax, Peter F. Patel-Schneider, Patrick Hayes and Ian Horrocks, W3C Recommendation, 10 February 2004, http://www.w3.org/TR/owl-semantics/. **: OMG Unified Modeling Language (OMG UML), http://www.omg.org, November, 2007.

the two-dimensional table of part of mapping rules between OWL concepts and UML elements. The second column in Table 1 is the concepts of OWL Full, the third column is the corresponding concept of UML and the fourth column is additional notes on each mapping. In order to refer to the classification standard of OWL Full, this study do not separate the directly mapping and the extension mapping as respective classification.

From the above analysis it could be seen that the structure of OWL is more complex than the UML in detail and part of the OWL stereotype do not have the unique corresponding UML stereotypes. So it is necessary to make the UML model converted to the OWL language environment in order to make it more widely used and also could make the constraint checking and concept hierarchy reasoning with the help of the reasoning machine in Protégé (Wang *et al*., 2004; Yang and Chung, 2006):

- "Attribute" of UML could be data type of a class which has the same semantics with non-directional association. In order to satisfy the consistency and uniqueness of OWL semantics, the "Attribute" of UML should be mapped with "DatatypeProperty" of OWL and the "Association" of UML should be mapped with "ObjectProperty" of OWL
- Relationship of "UnionOf" between the two classes in OWL could be represented by the combination of two generalization relationships in UML, it is defined as follows:

$$A = B\cup C \rightarrow B\subseteq A \wedge C\subseteq A$$

- The relationship of "IntersectionOf" between the two classes in OWL could be represented by the combination of two generalization relationships in UML, it is defined as follows:

$$A = B\cap C \rightarrow B\subseteq A \wedge C\subseteq A$$

- The concept of "EquivalentClass" in OWL could be represented by the relationship of "Mutual generalization" in UML and also the concept of "EquivalentProperty" could be represented by the relationship of "Mutual generalization" in UML, it is defined as follows:

$$A = B \rightarrow A\subseteq B \wedge B\subseteq A$$

- The class could be defined by enumeration in OWL, but it could not be enumerated in UML. However, the enum class "OneOf" of OWL could be mapped with "objects" of UML. The object would be referred as a special kind of class. The object is an instance of class in UML
- In UML the relationships among the classes are mutually exclusive by default, therefore, the relationship of "DisjointWith" in OWL don't need to have the mapping described in UML

## CONVERSION PROCESS BETWEEN UML AND OWL

Although, ontology modeling tool Protégé provides the extensive plug-in for UML storage and allow mutual conversion between OWL and UML, the plug-in is not perfect currently, especially the Protégé does not support the input of definitions of UML, such as "association classes", "n-ary associations", "generalization of associations", "association end navigability" and "attribute changeability" (Pedrinaci *et al*., 2004; Guizzardi *et al*., 2004).

Duric (2004) proposed a kind of definition of tag value and stereotype in UML model based on Ontology UML Profile (OUP), in this way, a UML class can be described as a union set of two classes. The OUP framework is adaptable to use stereotype to build a new UML model, but it could not deal with the existing UML models, because these models does not include necessary attributes such as tag value at the beginning of building. In the face of this problem, Object Management Group (OMG) which is an industrial standardization organization to develop the distributed object technique and the object management proposed the meta model strategy about ontology definition. In this strategy the mapping relationships between OWL and UML were put forward, although this is not a standard specification, it provides a good guidance for the subsequent research.

Firstly, the "Poseidon For UML 6.0.2" would be used to build UML model as a basic tool which has good support for XML-based Metadata Interchange (XMI) in order to convert the UML model into the XMI document. Main function of XMI is easy for data exchange between modeling tools and metadata repositories in all kinds of distributed heterogeneous environment. The UML modeling technology of OMG and the metadata structure of W3C are merged into a unified framework of XMI through the integration of three key industry standards (XML, UML and MOF), so the developers of each distributed system could easily share the object models and metadata on the internet. The MOF (Meta Object Facility) refers to the "metamodeling" standard and metadata storage repository of OMG.

Secondly, the "XSLTPROC Processor of Libxslt" would be used to convert the XMI document to XML document that the Protégé supports (Evermann, 2009). The "XSLTPROC Processor" is open source software engineering (http://xmlsoft.org/XSLT/) based on XSLT 2.0 (XML Style-Sheet Language Transformation) and XML Schema 1.0 framework. XSLT is extensible stylesheet language transformations recommended by the W3C, it and XSL-FO (Formatting Objects) form the extensible stylesheet language (XSL) specification. XSLT is the language of conversion to convert an XML document into another document. XPath is used in XSLT to choose all or part of the data from the source document and then to generate additional XML document or other file formats that can be directly displayed or printed. XSLT is a declarative language, namely the XSLT program itself only contains some transformation rules and these rules could be applied recursively to the conversion process. The "XSLT processor" would determine which rule in the XSLT is used first and then make the corresponding transformation operations according to the priority.

Finally, the OWL file outputted from the conversion would be inputted into the ontology modeling tool Protégé and make the reasoning test in order to validate the accuracy of grammar rules and the logic of semantic structure.

The working process of the above steps is shown in Fig. 1. It is important to note that the conversion from UML to OWL is reversible process. Similarly the conversion from OWL to UML could be inferred from Fig. 1.

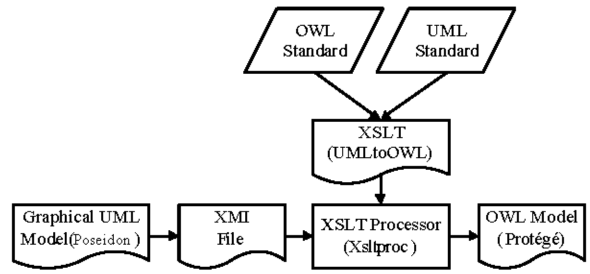


Fig. 1: Conversion process from UML to OWL

## UML MODEL FOR COLLABORATIVE IN MANUFACTURING SUPPLY CHAIN

Based on the mapping rules between the UML model and the OWL ontology model, through the way of building the UML profile of OWL the existing UML modeling tools could be used to build the OWL ontology model visually and easily. Xu *et al.* (2007) proposed a UML class diagram of Production which has been converted to the abstract syntax of OWL by the JAVA, but obviously the result based on Java is not easy to other ontology modeling tools to identify and operate. According to the UML class diagram of Production, a UML class diagram which contains the collaborative members in manufacturing supply chain is established based on the UML modeling tool "Poseidon For UML 6.0.2", as shown in Fig. 2.

## IMPLEMENT OF CONVERSION

The XMI file which is outputted by the "Poseidon For UML 6.0.2" was automatically converted based on UML2OWL. It's important to note that the XMI file maybe contains the Chinese characters because of the version of the "Poseidon For UML", so it is necessary to replace the Chinese characters with English characters for the requirements of Protégé. The code snippet of XMI file is shown in Table 2 and the code snippet of OWL file which was automatically converted is shown in Table 2 and the part of the semantic mappings between XMI and OWL are analyzed in Table 3.

## TEST OF CONVERSION RESULT

Pellet is developed by the MindSwap laboratory in the College Park campus, University of Maryland. It is a kind of reasoning machine of description logic based on Tableaux algorithm. As a kind of open source system

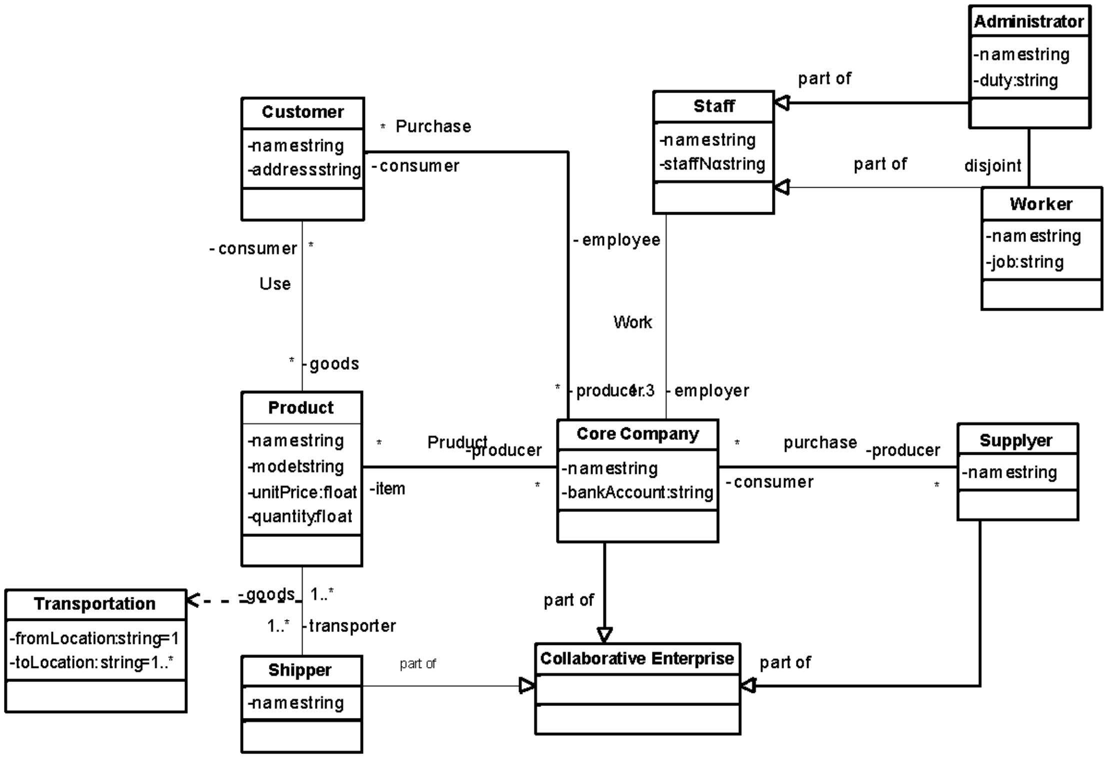


Fig. 2: UML model for collaborative in manufacturing supply chain

Table 2a: Code snippet of XMI file

```
<UML:Class xmi.id = 'Ia7ad660m11a86ea68cfmm7cda' name = 'Administrator'
visibility = 'public' isSpecification = 'false' isRoot = 'false' isLeaf = 'false'
isAbstract = 'false' isActive = 'false'>
<UML:GeneralizableElement.generalization>
<UML:Generalization xmi.idref = 'Ia7ad660m11a86ea68cfmm7b4e'/>
</UML:GeneralizableElement.generalization>
<UML:Classifier.feature>
<UML:Attribute xmi.id = 'Ia7ad660m11a86ea68cfmm7c76' name = 'name'
visibility = 'private'
isSpecification = 'false' ownerScope = 'instance' changeability = 'changeable'/>
<UML:Attribute xmi.id = 'Ia7ad660m11a86ea68cfmm7c64' name = 'duty'
visibility = 'private'
isSpecification = 'false' ownerScope = 'instance' changeability = 'changeable'>
<UML2:TypedElement.type>
<UML:DataType xmi.idref = 'Ia7ad660m11a86ea68cfmm7e30'/>
</UML2:TypedElement.type>
</UML:Attribute>
</UML:Classifier.feature>
 </UML:Class>
```

**Code snippet of OWL file**

```
<owl:Class rdf:about="#Administrator">
          <rdfs:subClassOf rdf:resource="#Staff"/>
      </owl:Class>
      <owl:Class rdf:about="#Administrator">
           <rdfs:subClassOf>
                <owl:Restriction>
                     <owl:onProperty rdf:resource="#disjoint_Ia7ad660m11a86ea68cfmm7b2e"/>
                     <owl:maxCardinality
rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:maxCardinality>
                </owl:Restriction>
           </rdfs:subClassOf>
```

Table 2: Continue

```
12              <rdfs:subClassOf>
13                  <owl:Restriction>
14                      <owl:onProperty rdf:resource="#disjoint_Ia7ad660m11a86ea68cfmm7b2e"/>
15                      <owl:minCardinality
16   rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:minCardinality>
17                  </owl:Restriction>
18                </rdfs:subClassOf>
19        </owl:Class>
20        <owl:DatatypeProperty rdf:ID="name">
21            <rdfs:domain rdf:resource="#Administrator"/>
22        </owl:DatatypeProperty>
23        <owl:DatatypeProperty rdf:ID="duty">
24            <rdfs:domain rdf:resource="#Administrator"/>
25        </owl:DatatypeProperty>
```

Table 3: Part of the semantic mapping between XMI and OWL

| | |
|---|---|
| a1→b1 | UML:Class→owl:Class |
| a8→b20, a11→b23 | UML:Attribute→owl:DatatypeProperty |
| a4→b2 | UML:GeneralizableElement→rdfs:subClassOf |
| a10→b21, a13→b24 | Conversion of the scope of attribute |
| a1→b9, a1→b16 | Conversion of the association end multiplicity of class |

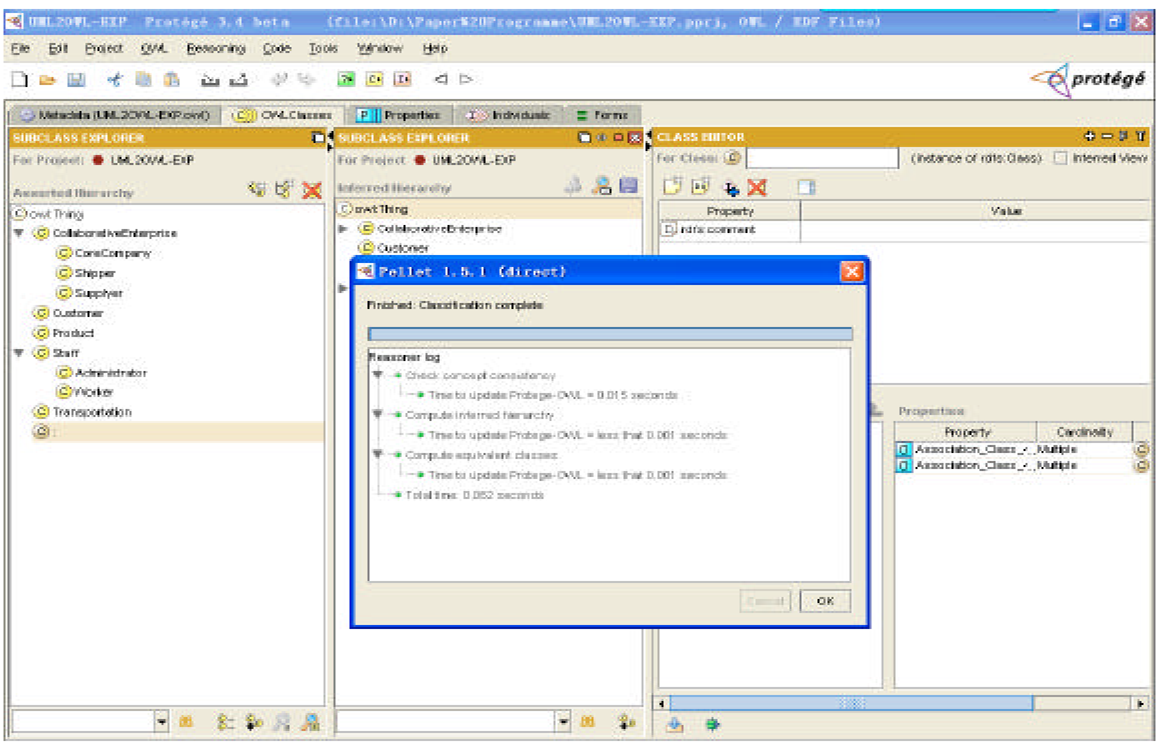


Fig. 3: Syntax check on ontology model for collaborative in manufacturing supply chain

based on Java, the “Pellet 1.5.1” has been integrated in the direct reasoning function module of the “Protégé 3.4 beta”.

The OWL file which has been generated from the UML class diagram of collaborative members in manufacturing supply chain by the method of automatic conversion was imported into the Protégé and the “classify taxonomy” function was used to have a reasoning test for the following three aspects: (1) Concept consistency, (2) Inferred hierarchy and (3) Equivalent classes.

As shown in Fig. 3, the duration of inspection process is a total of 0.062 sec, the results show that the OWL file automatically conversed is accurate and

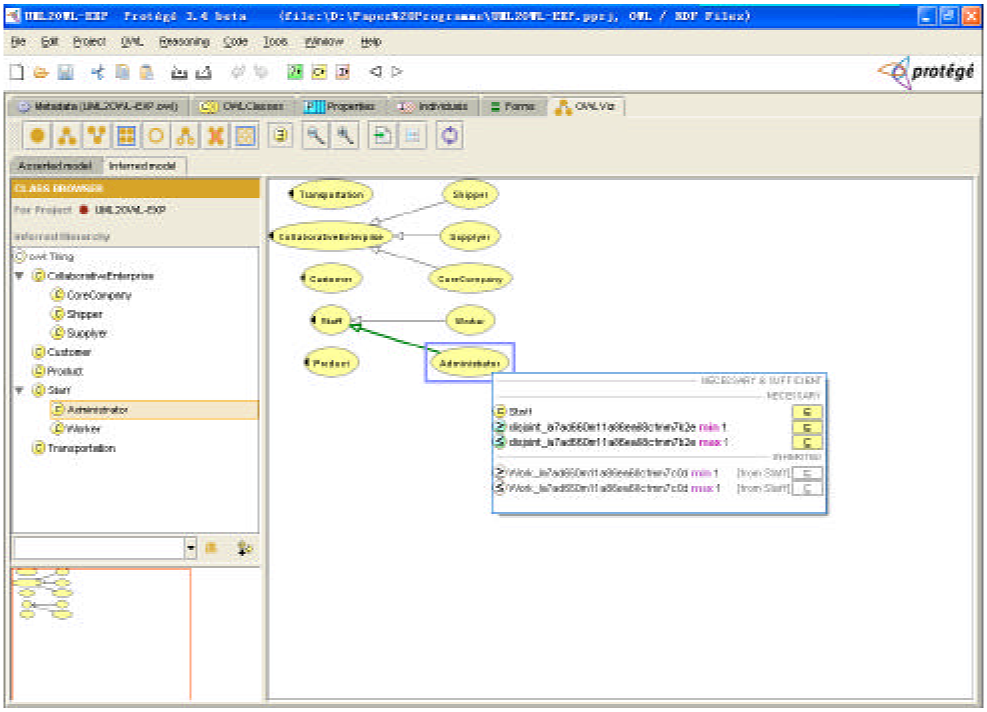


Fig. 4: Reasoning and validation on ontology model for collaborative in manufacturing supply chain

effective on the rules of grammar and could be fully compatible with the source file requirements of ontology modeling tool.

Figure 4 shows that the asserted hierarchy by the input of XMI file is completely consistent with the Inferred Hierarchy by the reasoning. Through the further analysis the result could be drawn that the ontology model is the same with the UML class diagram of collaborative enterprise in semantics.

## CONCLUSION

It has the important significance for the success and popularization of knowledge modeling to determine the correspondence and heterogeneity between the various kinds of knowledge representation models and provide the applicable conversion tools. According to the above study, the method of automatic conversion from the UML class diagram to the OWL file that was proposed in this study is feasible. Through the application of the related tools and programming, the automatic conversion could be realized correctly. Because of the combination of UML language and OWL language, the ontology knowledge model could be more effectively developed with the help of the rich object-oriented graphics expression function by UML.

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