Ontology-based Semantic Annotations for Business Processes in BPMN2.0

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Abstract. This paper analyzes the reason of BPMN emergence and points out that business processes in BPMN2.0 need semantic information to align Business and IT. In order to supplement semantic information in BPMN2.0, four methods of ontology-based semantic annotations are proposed and they are all built on the extension mechanism of BPMN2.0. The advantages and disadvantages of the four methods are subsequently discussed. This paper also discusses how semantic annotations benefit the vertical model transformation of business processes.

1 Introduction

Before the advent of computers, business processes are written in papers and performed by human beings. After information systems came out in computer science domain in 1970s [1], business processes were partially implemented by application logics (software) [2], which improved the management efficiency and productivity of companies. However, all of business processes were buried in software, and they were not easy to monitor by managers in companies. So in 1990's, workflow management systems (WMS) appeared, and they were later renamed Business Process Management Systems (BPMS), which can design, implement, execute, manage and analyze business processes explicitly [3]. Unfortunately in WMS/BPMS, business processes description languages were derived from the traditional programming languages and they were difficult for business analysts to learn and use [2]. It means that there is a wide gap between business domain and IT domain. During the alignment of business and IT, BPMS and SOA went together to realize business agility [4] – companies could be more rapidly adapted to business changes from customers, market or themselves. As web service is de-facto implementation protocol of SOA, nowadays BPMSs are more and more based on web service-based XML execution languages [5]. However, these languages such as WS-BPEL[6] are still oriented to IT engineers, not to business people. In order to address the interoperation of business processes at human-level [5], BPMN was created and published out in Version 1.1 by OMG in 2008. In order to model collaborations between companies, some important concepts such as "conversation" and "choreography" were added into BPMN2.0 released in January 2011.

BPMN2.0 can provide business people and IT engineers with a common and user-friendly graphical notation of business processes, but it can't make them have the same understanding of contents in business processes. That's to say BPMN2.0 defines the graphical notation and expression syntax of business processes, but it lacks semantic information about contents of business processes. So in order to align business and IT, semantic information of business processes is necessary. Besides, if business processes have semantic information, it will help to discover and reuse processes (or process fragments) [7-9] and it will also improve the automation degree of BPM [9-11].

Moreover, Model-Driven Architecture (MDA) [12]/Model-Driven Interoperability (MDI) [13] are attracting more and more attentions in both scientific and industrial domains to align business and IT, so MDA/MDI and business process management (BPM) are integrated together, especially in order to research collaborations/interoperability between enterprises from the viewpoint of MDA/MDI. [14, 15] use collaborative business processes to model their collaborations at the computation-independent model (CIM) level and BPMN is the preferable model language. [14, 15] all point out that the modeling of collaborative business processes must be supported by ontologies. So this paper will provide four ontology-based methods to annotate semantic information into BPMN2.0-based business processes.

The rest of the paper is structured as follows. Section 2 presents the related work in the research domain of semantic business processes. Section 3 elaborates the four methods of ontology-based semantic annotations and compares them. Section 4 shows the benefits of semantic annotations to the vertical model transformation of business processes. Section 5 concludes the whole paper.

2 Related Work

In order to research semantic information of business processes, two aspects should be considered: which kind of information should be ontologized and how to represent the information. For the first aspect [16, 17], which are based on European SUPER project (Semantics Utilised for Process management within and between EnterPrise)[1], have proposed three kinds of ontologies: process ontology, organisational ontology and domain ontology. Process ontology describes the structure of business processes whereas organisation ontology describes the artifacts involved in business processes (such as actors, resources etc), and domain ontology provides information specific to a company. [16] also shows that the three kinds of ontologies have different contents in different phases of BPM lifecycle.

For the second aspect, we have two choices: first, represent whole business processes as ontologies including the structure and the content of business processes; second, add semantic annotation for contents of business processes. [18] has proposed a General Process Ontology and an application domain ontology to ontologize the structure and content of business processes. In order to do the experiments of semantic process retrieval, [19] has transformed approximately 5000 business

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[1] http://www.ip-super.org/

processes into OWL described by the concepts of MIT Process Handbook[2]. [20] has proposed semantic BPMN which constructs BPMN concepts in OWL and uses these definitions to instantiate BPMN processes. [20] has also proposed semantic BPEL (sBPEL), semantic Event Process Chain (sEPC) to describe business processes and it wants to transform business processes based on these ontologies into that based on BPMO and at last it hopes BPMO can bridge sBPMN, sEPC and sBPEL together. To achieve the goal, [21] has done the ontology-based translation of business process models from Business Process Modeling Ontology (BPMO) to sBPEL and from sBPEL to BPMO. This paper will discuss the second choice, like SAWSDL[3] realized by WSMO Studio[4].

3 Semantic Annotations for Business Processes in BPMN

In this paper, semantic annotations for business processes are based on ontologies, i.e., the annotations will refer to concepts, properties or instances in ontologies (shown in Fig. 1). However, the construction and distribution of ontologies are beyond the scope of this paper, so this paper will just focus on how to associate ontology with BPMN2.0-based business processes. Before that, we provide a concrete
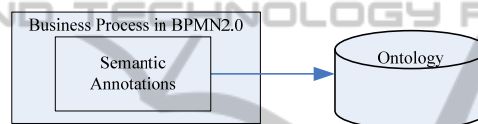
Fig. 1. Ontology-based Semantic Annotations for Business Processes.

example that indicates why a semantic annotation is necessary to business processes: in a company, for the preparation of an anniversary celebration, there are lots of tasks to do, one of which is to buy 5 beautiful notebooks as awards. To the organisers of the preparation activity, "notebook" maybe means "book with blank pages for recording notes or memoranda"[5]. However, if the preparation process of the celebration is supported by information systems and the task, "buy 5 notebooks", is implemented by IT engineers as "find a notebook provider on the Internet and send electronic request", to IT engineers, "notebook" may be "notebook computer (a small compact portable computer)"[5]. That's to say "notebook" has ambiguity in the "preparation" process. However, this is just one case for semantic heterogeneity [22, 23]. So the contents in business processes must be annotated with semantic information for disambiguation between different people. The following will explain how to realize the semantic annotation for BPMN2.0-based business processes.

BPMN2.0 metamodel provides an extension mechanism. This allows business process metamodel to be extended but to be still BPMN-compliant. In BPMN2.0 metamodel, such extensibility is implied in the definitions of "baseElement" (Page 64

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2 http://ccs.mit.edu/ph/

3 http://www.w3.org/TR/sawsdl/

4 http://www.wsmostudio.org

5 http://wordnetweb.princeton.edu/perl/webwn

of [5]), "rootElement" (Page 65 of [5]), "documentation" (Page 64 of [5]), and "extension" (Page 60 of [5]. This paper proposes the four ontology-based methods of semantic annotations. Before the elaboration of the four methods, the outline of BPMN2.0 files is provided in Fig. 2 (a). BPMN2.0 files are based on XML, and their root element is "definitions" (Page 54 of [5]), and normally it contains two scopes: one for the structure of collaborations/choreographies/processes and the other for the visualization of all graphical notations in business collaborations/choreographies/ processes.
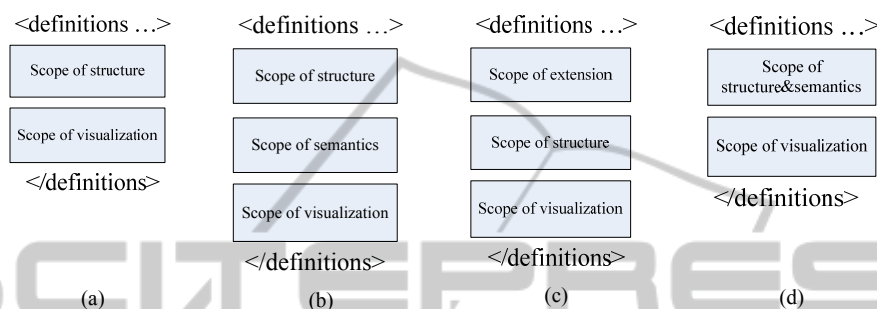

Fig. 2. Structures of BPMN2.0 Files.

3.1 "rootElement"-based Semantic Annotation

According to BPMN2.0 metamodel, "rootElement" is a child element of "definitions" and it can be replaced by its subclasses, so we can define a subclass of rootElement's data type and create a corresponding element to replace "rootElement". The schema definition for the scope of semantics is as follows.

Schema definition for semantic annotations of BPMN2.0 (not complete)

```
<xs:complexType name="tSemanticAnnotation">
<xs:complexContent>
<xs:extension base="bpmn20:tRootElement">
<xs:sequence>
<xs:element name="detail" type="tSemanticDetail"
        minOccurs="0" maxOccurs="1"/></xs:sequence>
<xs:attribute name="bpmnElement" type="xs:QName"/>
<xs:attribute name="ontologyRef" type="xs:anyURI"/>
<xs:attribute name="level" type="tMDALevel"/>
</xs:extension></xs:complexContent>
</xs:complexType>
<xs:complexType name="tSemanticAnnotationList">
<xs:complexContent>
<xs:extension base="bpmn20:tRootElement">
<xs:sequence>
<xs:element name="semanticAnnotation"
        type="tSemanticAnnotation" minOccurs="0"
        maxOccurs="unbounded"/>
</xs:sequence></xs:extension></xs:complexContent>
</xs:complexType>
<xs:element name="semanticAnnotationList"
        type="tSemanticAnnotationList"
        substitutionGroup="bpmn20:rootElement"/>
```

In the above code, the type "**tSemanticAnnotation**" defines which attributes should be included in the semantic annotation for an element in BPMN2.0-based business processes. Its attribute "**bpmnElement**" points to a corresponding element in the scope of structure. The attribute "**ontologyRef**" points to a concept defined in an ontology and the concept explains what the above "bpmnElement" means. The attribute "**level**" means an MDA level at which the semantic annotation is. The sub-element "**detail**" contains the detailed semantic information of the annotated element and it can appear at most one time in a semantic annotation, for example, for a certain task in a business process, there is not any corresponding concept/instance in the dependent ontology, then the task can be described by its actors, action, resources and other conditions which may have corresponding concepts/instances. Besides, the list "**semanticAnnotationList**" contains all required semantic annotations for elements in business processes.

After applying the above schema into a business process in BPMN2.0, the BPMN2.0 files will be like Fig. 2 (b). The following gives an example of the scope of semantics (the *namespace* in Italic is the namespace of the dependent ontology).

Example of "rootElement"-based semantic annotation

```
<bpmnsa:semanticAnnotationList id="sid-1">
<bpmnsa:semanticAnnotation id="sid-2_s"
 bpmnElement="sid-2"
 ontologyRef="{namespace}/logisticOnto.owl#TrainTicket"
 level="CIM"/>
</bpmnsa:semanticAnnotationList>
```

However, this method requires that the new schema and the original BPMN2.0 schema (metamodel) share the same "targetNamespace", and BPMN2.0 schema must include the new schema. That's to say the original BPMN2.0 schema will be modified, and this is the drawback of the method.

3.2 "extension"-based Semantic Annotation

According to BPMN2.0 metamodel, "extension" is a sub-element of "definitions", and it can be extended. So this method is to add semantic annotations into the "extension" element. The definition of semantic annotations is the same as that in the first method. After applying this method into a business process, the BPMN2.0 files will be like Fig. 2 (c). The following gives an example of the scope of semantics. In this method, the scope of semantics is included in the scope of "extension", not directly stored as the sibling scope of business processes' structures like "rootElement"-based method, so the representation style of semantic annotations in this method is less clear than that in "rootElement"-based method.

Example of "extension"-based semantic annotation

```
<extension definition="semanticAnnotation">
<documentation>
<bpmnsa:semanticAnnotationList id="sidl-1">
<bpmnsa:semanticAnnotation id="sid-2_s"
 bpmnElement="sid-2"
 ontologyRef=
           "{namespace}/logisticOnto.owl#TrainTicket"/>
</bpmnsa:semanticAnnotationList>
</documentation></extension>
```

3.3 Attribute/Element-based Semantic Annotation

In BPMN2.0 metamodel, the type of "baseElement" makes it possible to add new attributes or new elements into it, and fortunately collaboration, choreography, process, task, artefact, event, message, gateway, participant and expression are extended based on the type of "baseElement", so all of the above concepts can add a new attribute to point to a concept defined in an ontology. The attribute can be defined as follows.

Attribute definition for semantic annotation

```
<xs:attribute name="ontologyRef" type="xs:anyURI" />
```

So after applying such annotation method, the extended business process is obtained and the following shows one fragment.

Example of attribute-based semantic annotation

```
<dataObject id="sid-2" isCollection="false"
  name="ticket"
  bpmnsa:ontologyRef=
           "{namespace}/logisticOnto.owl#TrainTicket"/>
```

In this method, all semantic annotations are scattered in BPMN2.0 files, not like the above two methods where all semantic annotations are collected in one scope. The structure of BPMN2.0 files is like Fig. 2 (d). This method is similar to SAWSDL.

3.4 "textAnnotation"-based Semantic Annotation

As "textAnnotation" is extended from the type of "baseElement", so it has extensibility inherently. And "textAnnotation" can be associated with activities, events, gateways, message flows, sequence flows and other objects whose type is derived from the type of "baseElement". So "textAnnotation" can be used as a method of semantic annotations. However, "textAnnotation" is associated with an annotated element by an association, not like the above three methods which associate semantic annotations and annotated elements by ID mappings ("bpmnElement" in Section 3.1). In a business process, the usage of "textAnnotation"-based semantic annotation is as follows and the structure of BPMN2.0 files will be like Fig. 2 (d).

Example of "textAnnotation"-based semantic annotation

```
<textAnnotation id="sid-3" textFormat="text/plain">
<text>
<bpmnsa:semanticAnnotation id="sid-2_s"
 ontologyRef=
           "{namespace}/logisticOnto.owl#TrainTicket"/>
</text></textAnnotation>
```

In terms of the above elaboration of four methods, the first two methods collect all semantic annotations together in the scope of semantics, instead the second two methods merge semantic annotations within the scope of business processes' structures. Table 1 compares the four methods in detail.

Table 1. Comparison between four semantic annotation methods of business processes.

Semantic Annotation	advantages	disadvantages
"rootElement"-based	Keep all semantic annotations together;	Modify the metamodel of BPMN2.0;
"extension"-based	Keep all semantic annotations together;	Less clear than "rootElement"-based SA
attribute/element-based	Semantic annotations are attached directly to designated BPMN elements;	All semantic annotations are scattered in the structure scope of BPMN files;
"textAnnotation"-based	Semantic annotations are attached to designated; BPMN elements	Not directly mapped; "textAnnotation" appears everywhere in BPMN graphical diagrams;

The above four ontology-based semantic annotation methods can be adopted by BPMN2.0 Tools such as BizAgi Xpress[6], Oracle BPM Suite[7], Bonita Open Solution[8] etc. According to Table 1, the second method is preferable. If BPMN2.0 tools want to add semantic annotations into business processes, they must provide IT engineers with a graphical user interface (GUI) which could show all concepts/instances in dependent ontologies and which should also easily associate them with graphical elements in business processes. Of course, these tools should also provide a GUI for IT engineers to create detailed semantic annotations -- "detail" in Section 3.1, which can help generate new concepts/instances in dependent ontologies.

4 Semantic Annotations and Model Transformation

Besides facilitating process (or process fragment) discovery and reuse, semantic information in business processes can also help model transformation in MDA research domain. In [15], a process-based method for enterprise interoperability has been proposed and it is integrated with MDA. At the CIM level, this method uses collaborative business processes to describe collaboration requirements between

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[6] http://www.bizagi.com/index.php?option=com_content&view=article&id=19&Itemid=100

[7] http://www.oracle.com/us/corporate/press/079865

[8] http://www.bonitasoft.com/

enterprises and after several model (business process) transformations, it is expected to generate several executable business processes. Each business process transformation will need semantic information retrieved from ontologies and add new information into generated business processes. Semantic Annotations for business processes can be a suitable method to support such business process transformation.

Fig.3 shows a general model transformation in the method of [15] and the transformation takes advantage of semantic annotations. In Fig. 3, Business Process i has the existing semantic annotations which point to ontology, especially point to Ontology i, and the newly generated Business Process j contains new semantic annotations besides the originals. The new semantic annotations also point to ontology, especially points to Ontology j. During the transformation from Business Process i to j (from MDA high level to MDA low level), the mapping between Ontology i and j will be needed. With the help of the mapping, the transformation will find the concepts/instances in Ontology j corresponding to concepts/instances in existing semantic annotations of Business Process i. The new semantics will be added into Business Process j.
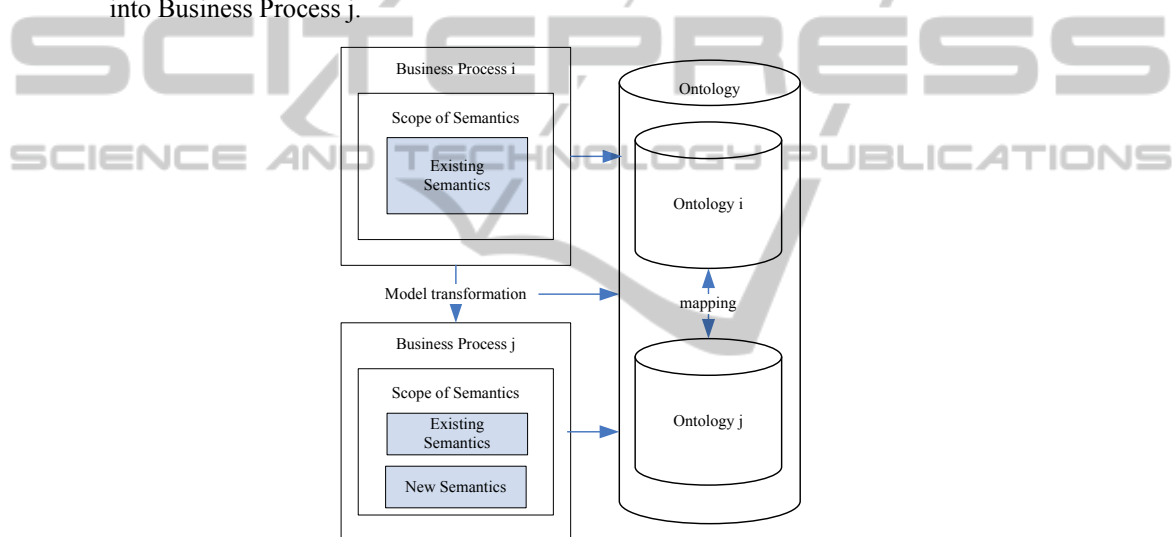
Fig. 3. Semantic Annotations in Business Process Transformation.

From the above narration, semantic annotations of business processes are very useful for vertical model transformation (from MDA high level to low level).

5 Conclusions

Business processes need semantic information during the alignment between business and IT. In order to supplement semantic information in BPMN2.0-based business processes, this paper has presented four methods of ontology-based semantic annotations and these methods are all built on the existent extensibility mechanism of BPMN2.0. After the comparison of the four methods, the "extension"-based semantic

annotation method will be preferable to the other three methods. This paper has also shown that semantic annotations are helpful to the vertical transformation of business processes (a business process is regarded as a model in MDA).

Apart from bringing benefits to BPMN2.0-based business processes, semantic annotations are also beneficial to ontologies. This paper has indicated that the detailed semantic annotations will help to generate new concepts/instances to enhance contents of ontologies. Furthermore, semantic annotations imply the reversible associations between business processes and ontologies, hence some concepts/instances in ontologies have corresponding structural elements in business processes and they can find their preconditions/post-conditions through business processes. In fact, business processes can be regarded as contexts for some concepts/instances in ontologies. So, BPMN2.0-based business processes are one kind of structural annotations for ontologies.

Acknowledgements

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