Mappings from OWL-s to UML for Semantic Web Services

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Abstract. As a member of resources on Semantic Web, Web Services become increasingly important to realize accurate composition for interoperation between human beings and information systems. In order to address the need for semantic annotation of existing Web Services, a special UML profile can be built upon UML metamodel and MMFI4Ontology Registration for Semantic Web Services described with OWL-s. Then the mappings from OWL-s to UML are defined in detail to indicate that our UML profile and transformation rules can be used to represent services with UML activity models. Efforts on our UML profile and further mappings can enrich the semantics of ubiquitous Web Services, facilitate services modeling for domain experts and make it easy to update current tools for supporting growing services on semantic web.

1 Introduction

As a crucial force of the next generation web, Semantic Web Services are raised to discover and access ubiquitous service resources in a more easy and accurate way. For this purpose, semantic markup of Web services, user constraints and Web agent generic procedures should be involved to augment the capability of conversation between human beings and information systems, together with the interoperation among systems [1]. As the base of information sharing, accessing and reuse, ontology is deemed as the key technique to provide rich semantic annotation and explicit interpretation. With the significant demands in academia and industry, ontology can be used to capture the semantics of various sources and give them a concise, uniform and declarative description. Either web sites or Web Services tend to employ ontology for service description and classification [2].

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In the family of ontology description languages, OWL (Web Ontology Language) [3] proposed by W3C (World Wide Web Consortium) has become the most popular one for diverse applications based on ontologies. OWL is tended to provide a standard specification for various resources on the web, from entities to services. Owing to the important role that services play, a specific OWL profile for Web Services (OWL-s for short) is designed as an extended ontology language to reflect the fact that it provides a standard vocabulary that can be used together with the other aspects of the OWL description languages to create service description [4]. Since both OWL and OWL-s are based on the syntax of XML (eXtensible Markup Language), it is difficult for common customers to use them conveniently. Furthermore, OWL-s based applications lack sufficient supports from existing modeling tools, especially the ones with friendly interfaces and simple operations. Different from OWL and OWL-s, UML (Unified Modeling Language) has been regarded as the standard modeling language in software engineering. It has received wild attention, acceptance and tool support due to its visual views and easy manipulation. Analysis on those two languages gives rise to a hotspot of current research, i.e. to establish transformation between them and update existing UML tools for Semantic Web Services. If so, service access, service invocation and other web applications can be promoted greatly.

This paper contributes to extending basic activity elements in UML 2.0 standard [5] and grouping them as a UML profile for Semantic Web Services. In this profile, a common registry structure from Framework for Metamodel Interoperability: Metamodel for Ontology Registration (MMFI4Ontology Registration for short) [6] is also combined to register ontologies related to Web Services. Further mappings are then defined to convert Web Services described with OWL-s into UML Activity Diagrams. In terms of our profile and mapping rules, Web Services on Semantic Web can be represented graphically and embraced with more existing tools, which might promote discovery and invocation of OWL-s based Web Services for different needs.

This paper is organized as follows: Section 2 introduces OWL-s briefly; Section 3 provides a specific UML profile for Semantic Web Services; in Section 4, mapping from OWL-s to UML is specified by detailed rules; Section 5 exemplifies how our mapping rules fit the specific cases; Section 6 covers related work, followed by conclusions and future work in Section 7.

2 Overview of OWL-s

OWL-s is proposed by W3C as a particular OWL profile for Web Services on Semantic Web. It supplies semantic and functional description of services and automation services tasks including discovery, invocation, composition and interoperation [7]. In general, an OWL-s based description of Service represents reference for a declared Web Service, which contains three essential parts as follows:

- ServiceProfile gives the advertising information of services, with respect to relevant information of service provider, service requester and service itself. Service shows what it does by presenting a ServiceProfile, so ServiceProfile will be necessary for customized service discovery and location.
- ServiceModel describes the function of services and specifies how to use them. Service is described by ServiceModel, including the trigger condition, the steps it should follow, the results and the corresponding effect as well. In those three parts, ServiceModel is of quite importance and complexity.
- ServiceGrounding is supported by Services and specifies the means by which users can access to a specific service. In contrast to ServiceProfile and ServiceModel, ServiceGrounding concentrates on concrete realization of service, rather than its abstract representations.

Those three parts are the main components of upper ontology of services, which provide an overall description, especially functional description, for Web Services and the details on their executable processes. As such, OWL-s can be used to represent semantics of Web Services by means of this uniform mechanism.

3 UML Profile for Semantic Web Services

To make use of Web Services, it is necessary to provide the description of services and the means by which they are located, selected as well as composed. In this section, a particular UML profile for Semantic Web Services will be established on two existing metamodel standards.

The first one is UML 2.0 standard, in which three extension mechanisms, i.e. stereotype, tagged value and constraints are offered for new model elements based on existing or defined ones. Stereotypes define how to extend defined metaclasses for specific domains. Tagged values refer to the new values of properties. And constraints describe restrictions that applied to existing metamodel elements. A UML profile represents a set of extended elements for a specific scenario. Considering Semantic Web Services, referred elements mainly come from Kernel package, Action package and Activity package of UML metamodel.

Table 1. Mappings for Semantic Web Services

Element in OWL-s	Metaclass in UML	Type of extensions
Service	Class	stereotype
Service Profile	Class	stereotype
Service Process	Class	stereotype
Service Grounding	Class	stereotype
presents	Association	stereotype
describedBy	Association	stereotype
supports	Association	stereotype
Category	Comment	tagged value

On one hand, the main structure of Web Services can be represented by extended metaclasses from Kernel package, in which classes, properties, associations and etc. are covered. In our UML profile, stereotypes can be respectively marked to “Service”, “Service Profile”, “Service Process”, “Service Grounding” and the relationships between them to generate a Class Diagram of Web Services. Mappings for Semantic Web Services and corresponding extension mechanisms they adopted are listed in Table 1. On the other hand, Web Services concentrate much more on dynamic activities, including service discovery, invocation, composition and interoperation. As a result, metaclasses from Action package and Activity package should also be employed, as the blue parts in Figure 1 shows.

The second standard is ISO MMFI4Ontology Registration, which is provided as a common framework to register ontologies, manage corresponding evolution information and enable semantic interoperation between them. MMFI4Ontology Registration contains a language-independent structure with three layers to capture basic semantics and structure of ontologies that is Ontology-Ontology Component-Ontology Atomic Construct [8], In our proposed framework, Ontology consists of Ontology Components and Ontology Component consists of Ontology Atomic Constructs. Under the guidance of this framework, ontology can be registered to annotate Web Services, even be employed to classify services and promote applications based on them. In Figure 1, Category of services can be addressed by a registered ontology in MMFI4Ontology Registration.

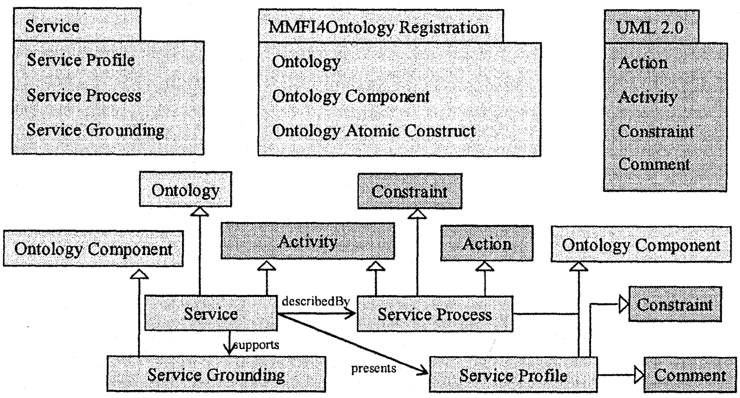

Fig. 1. UML profile for Semantic Web Services.

Based on the proposed UML profile for Semantic Web Services, the main concepts and properties in Web Services can be represented semantically. However, Figure 1 only illustrates the relations between Web Services and activity description part of UML 2.0 standard in brief. Further details will be discussed in Section 4.

4 Mapping from OWL-s to UML

It's widely known that essential elements, including static structure diagrams and dynamic behavioral diagrams are provided in UML 2.0 standard for domain modeling. Although description of services involves descriptions for entities and processes, more attention will be paid to service processes in this section. That is, detailed mappings rules will be defined here to specify transformations from OWL-s process model to UML dynamic diagrams.

Generally speaking, services refer to a group of processes or activities that will be executed in a certain sequence. According to the proposed UML profile for Semantic Web Services, services as a whole can be first represented as a stereotyped complex activities. Since a service consists of atomic processes and other composite processes, both Atomic Process and Composite Process in OWL-s should be represented as activities with respective stereotypes. Correspondingly, inputs and outputs of those activities are mapped to InputPin and OutputPin from UML Action package, while preconditions and their effects are referred to logical representation with restrictions. Trivial extended elements in our UML profile for ServiceProcess of Web Service are shown in Table 2.

Table 2. Mappings for ServiceProcess

Elementin OWL-s	Metaclass in UML	Type of extensions
process.SimpleProcess	Activity	stereotype
process.CompositeProcess	Activity	stereotype
process.AtomicProcess	Activity	stereotype
process.preconditions(s)	Constraint	constraint
process.input(s)	Action.InputPin	stereotype
process.output(s)	Action.OutputPin	stereotype
process.effect(s)	Constraint	constraint
process.parameters	Activity.Parameter	stereotype
process.condition	Constraint	constraint
process.collapseto	Association	stereotype
process.expandto	Association	stereotype

As far as composite process is further concerned, it is decomposable into other composite process or atomic processes, and the decomposition is under the guidance of different control constructs, such as process.sequence, process.split-join, etc. Then various kinds of activity nodes can be marked with stereotypes to represent Control Constructs and their subclasses in OWL-s, as Table 3 lists. For example, both the metaclass iterate and its two subclasses are mapped to LoopNode in Activity model here. Notice that no mapped notation is found for process.any-order now.

In terms of mapping rules specified in those two tables, Semantic Web Services described with OWL-s can be transformed into respective UML Activity Diagram. Only mappings from OWL-s to UML, rather than both-way transformation between them, are discussed in this paper. The basic idea of transformation may be helpful for the next study on transformations from UML to OWL-s.

Table 3. Mappings for Control Constructs in ServiceProcess

Element in OWL-s	Metaclass in UML	Type of extensions
process.sequence	Activity.SeqenceNode	stereotype
process.choice	Activity.DecisionNode	stereotype
process.split	Activity.ForkNode or/and Activity.DecisionNode	stereotype
process.split-join	Activity.ForkNode or/and Activity.JoinNode	stereotype
process.any-order	Not Mapped in Activity Model	None
process.if-then-else	Activity.ConditionalNode	stereotype
process.iterate	Activity.LoopNode	stereotype
process.repeat-while	Activity.LoopNode	stereotype
process.repeat-until	Activity.LoopNode	stereotype

5 Example

In this section, a simple example is demonstrated to show how those mapping rules can fit for converting a specific OWL-s service description into a UML activity diagram when a real case is taken into account. The exemplary service introduced here is called BravoAir Reservation, which is provided by W3C in [9].

Based on the OWL-s specification, BravoAir reservation service consists of its own profile, process and grounding. The names of these three components and the relationships between them are specified in the following fragment documents. Following the mapping rules proposed in Table 1, we can easily generate the corresponding class diagram in Figure 2 to describe overall structure of BravoAir reservation service.

```
……
  - <service:Service
rdf:ID="BravoAir_ReservationAgent">
  <service:presents
rdf:resource="&website#Profile_BravoAir_ReservationAgen
t" />
  <service:describedBy
rdf:resource="&website#BravoAir_ReservationAgent_Proces
sModel" />
  <service:supports
rdf:resource="&website#Grounding_BravoAir_ReservationAg
ent" />
</service:Service>……
```

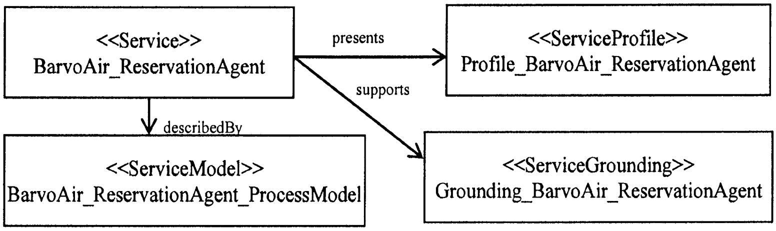

Fig. 2. UML class diagram for BravoAir reservation service

After the overall representation, we will concentrate on how to present activities in BravoAir_ReservationAgent_ProcessModel. BravoAir_Process is the core process in this process model. It contains two atomic processes GetDesiredFlightDetails and SelectAvailableFlight, along with one composite process named BookFlight. In terms of our UML profile and mapping rules proposed in Section 3, an activity diagram of BravoAir reservation service can be generated, as the right part of Figure 2 suggests. In this figure, all the processes in BravoAir service, including composite processes and atomic processes, are represented as different activities. The relevant inputs, outputs and other parameters are merged into corresponding control flows.

Meanwhile, Figure 2 also illustrates a general conversation named BravoAir Reservation Agent Process. First the GetDesiredFlightDetails is called. Its outputs involve airports, preferred time, round trip, etc. AvailableFlightItineraryList_Out then will be generated as one of the inputs of BookFlight. It's known that the outputs of Login, one of the sub-processes of BookFlight, indicate whether the user's details are confirmed or not. Correspondingly, the UML DecisionNode control flow construct is introduced here as a conditional choice to tell whether the BookFlight conversation can be implemented successfully according to defined sequence in the service. If all the input details are correct, the selected reservation will be confirmed and return an appropriate response that the customer will succeed in having a seat.

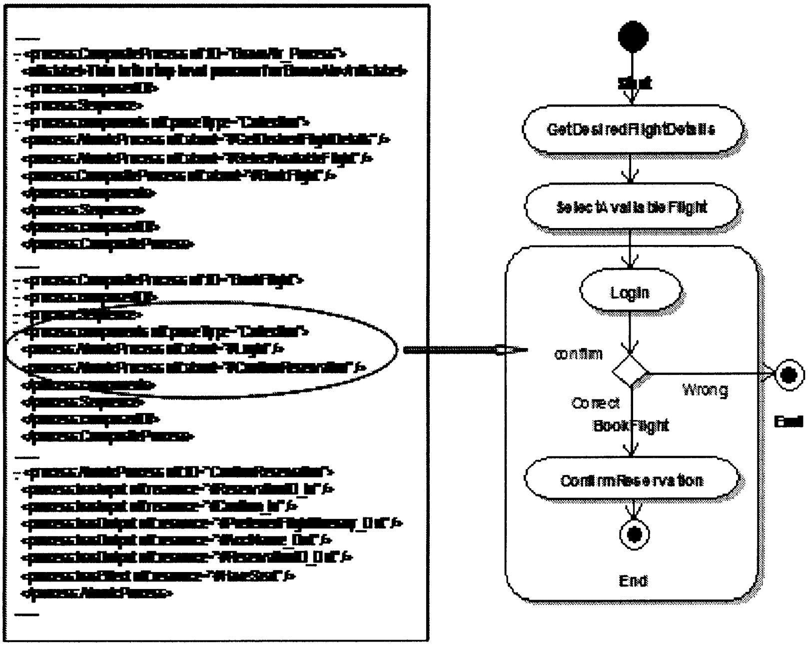

Fig. 3. Activity Diagram for BravoAir Process

6 Related work

Web Service Description Language (WSDL) is proposed by W3C to provide a model and an XML format for describing Web Services [10]. Till now, many tools have been developed to support and generate specific WSDL documents. However, poor semantics is attached to WSDL documents since they always work at syntactic level. Then misunderstanding might be caused by ambiguous descriptions. To handle with this problem, WSDL-s [11] is raised as semantic annotated WSDL to add semantics to existing description mechanism. Though both OWL-s and WSDL-s can be used to describe Web Services on Semantic Web, the former is of richer expressiveness than the later when semantic representation is taken into account. Moreover, domain experts and ending users may prefer OWL-s rather than WDSL during the process of specifying domain concepts and the relationships between them.

Web Service Management Framework- Foundation (WSMF-Foundation) is designed by Hewlett-Packard Company to make use of Web Services to provide the management interfaces to manageable resources [12]. WSMF builds upon the existing Web Services techniques, such as WSDL and SOAP [13], to define methods for Web Services management. But the basic foundation of WSMF, XML syntax and relevant standards, is of insufficient semantics. It will give rise to the fact that WSMF lacks of more powerful methods of discovering new manageable resources on Semantic web. Based on our UML profile for Semantic Web Service, WSMF can be similarly enhanced in expressiveness of semantic representation and capability of dynamic operations as well.

Ontology Definition Metamodel (ODM) [14] is proposed by Object Management Organization (OMG) to provide metamodels of the most popular ontology description languages and mappings between them, covering both ways syntax transformation between OWL and UML, etc. However, corresponding mappings in ODM only concentrate on the transformations from/to UML Class Diagram, Activity Diagram or other kinds of dynamic diagrams are beyond the scope of current version of ODM. In this paper, our UML profile for Semantic Web Service and mapping rules focus on the relations between OWL-s and dynamic parts of UML standard, which is stronger than ODM standard in expressiveness capability to some extend.

7 Conclusions and Future Work

In this paper, a UML profile for Semantic Web Services is established on the basis of two existing standards: UML 2.0 standard and MMFI4Ontology Registration. UML metamodel provides infrastructure elements and three extension mechanisms. And MMFI4Ontology Registration is reused to associate semantics with extended representation of Web Services, so that those registered ontologies can be used for further semantic interoperation based on them. Then detailed mappings are defined to convert OWL-s description of web services into corresponding UML activity diagram, covering respective mapping tables for OWL-s process model and its control constructs. Under the guidance of our profile and one-way transformation rules, not only can Web Services be annotated semantically, but also customized services might be generated with graphical representation by specifying those UML-based modeling methods.

In the near future, further efforts will be made on mappings from UML to OWL-s to supplement current transformation rules. In addition, we'll pay more attention to the research regarding dynamic composition of Semantic Web Services based on UML metamodel, followed by preserving semantic consistency in the case that ontology is of great importance.

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