Ontology-based semantic infrastructure for service interoperability *

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Abstract. In this paper, we provide a general overview of our recent research contributions, with focus on the proposed approach for building service ontologies to serve as an interoperability semantic infrastructure in web information systems.

1 Introduction

Interoperability issues related to the increasing need of cooperation and communication among users/applications over the Web are intensively addressed in the literature. In particular, Web-based information systems require advanced methods and tools to effectively support users in the localization and retrieval of information and services on the Web. Techniques and approaches for the organization and representation of semantic contents of information and services assume a relevant role. The problem of organizing semantic knowledge, according to classification schemes based on concepts and semantic links among concepts at different abstraction levels, is a relevant topic addressed by the research work on the Semantic Web and on ontologies for the Semantic Web [3]. Ontologies are considered as the enabling technology for the Semantic Web and methods and tools for ontology definition are being studied for interoperability purposes ([11, 13].

Techniques and approaches for the design of concept ontologies through classification techniques and for the definition of thematic views in order to support the users in the localization and retrieval of information and services on the Web are being developed [14]. Classification techniques based on matching and clustering algorithms have been studied to find and classify correspondences among elements of heterogeneous schemas [10].

The research team at University of Brescia has produced contributions to the development of classification techniques for analysis, matching and clustering of structured [6] and semistructured data in the framework of the integration tool environment ARTEMIS [7]. An ontology design methodology for knowledge sharing and service composition has been proposed in [4].

For service ontologies, DAML-S [1] has been proposed in the area of Semantic Web to describe service semantics and several formal models and languages have been proposed for handling services from a semantic point of view. Semantic

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descriptions are specifically needed for matchmaking between service demands and offers and for service dynamic discovery. Techniques for matchmaking have been studied taking into account quality of services [8, 12]. Recently, ontology-based discovery approaches are being developed [9].

The research team at University of Brescia has produced contributions to the development of techniques for service modeling and analysis in order to identify compatible services, i.e. services that can substitute each other in the execution of cooperative processes [4, 5].

In this paper, we provide an overview of our approach for building service ontologies to serve as an interoperability semantic infrastructure in Web information systems. The paper is organized as follows. Section 2 describes the methodological approach to service ontology design. Section 3 discusses future work.

2 Service ontology design

On purpose of service modeling and classification, a service model has been proposed in the context of MAIS project [2]. The model takes into account: the service provider perspective, specifying who provides the service, on what channel is provided, what the service does and how to invoke its functionalities; and the service requester perspective, associated to a particular user profile and operating in a particular context, that specifies who requires the service, the user's context and which level of quality is required. The model considers both functional and non-functional aspects.

Service functional description. A service is mainly described by a set of operations and I/O entities providing the service interface description. Pre- and post-conditions are stated on each single operation and on the whole service. They are logical expressions on I/O entities that must be verified before the execution of an operation or of the whole service and that are satisfied after the execution, respectively. Further characterization of services regards the order in which the operations are to be performed, at what input messages the service reacts and what output messages it produces during state transitions. These aspects are represented in the model by means of finite state automata, where each state transition is labeled with the input message that causes the transition and the output one that is produced by the transition.

Service non-functional description. With respect to the non-functional aspects, we consider that each service is characterized by a set of quality parameters. Some of them are general purpose parameters provided by available standard classifications (for example, ISO 8402, part of the ISO 9000 standard), but we consider also more specific application dependent quality parameters (for example, the number of credit cards accepted by an on-line ticket reservation service). Each quality parameter is described by means of a name, one or more measure units and a parameter type.

In our approach, functional aspects are used to organize services into the service ontology and to permit service discovery on the basis of user functional needs. Non-functional aspects are exploited to further improve the service discovery according to the user quality requirements. In particular, in the service ontology we represent services at different levels of abstraction and to this purpose we introduce three kinds of elements.

Concrete service. A concrete service represents a directly invocable service, that is, the description of the service implementation as proposed by the service provider. It is described in terms of interface, behavior, quality and implementation features. In our ontology design approach we analyze interface and behavioral description of concrete services to establish semantic relationships between them and to group them into sets (*clusters*) of so called compatible services.

Abstract service. An abstract service represents a cluster of compatible concrete services and is described by means of interface and quality parameters and it is not related to a particular implementation. Two kinds of relationships between abstract services are established, the `is-a` relationship, that holds when an abstract service offers at least the same functionalities of another one, and `is-part-of` relationship, that is obtained when an abstract service can be viewed as the composition of other ones.

Service categories. Service categories are chosen from available standard classifications (for example, the Universal Standard Products and Services Classification UNSPSC) to provide topic-based view on the set of underlying abstract and concrete services; each category is associated to one or more abstract services.

According to the presented service model and to the considered levels of abstraction, we developed a methodology to build a service ontology, articulated in three phases.

1. *Analysis.* In this phase concrete services are compared on the basis of their interface and their behavior to evaluate their similarity according to properly defined similarity criteria. Weighted semantic relationships are established among them on the basis of the performed similarity computation. Two concrete services are grouped in the same cluster when the weight of semantic relationships connecting them is greater than a given threshold (*similarity layer*).
2. *Abstraction.* In this phase for each cluster of similar concrete services an abstract service is built, following an integration process. In particular, operations and I/O entities which describe the interfaces of concrete services belonging to the same cluster are unified to obtain the abstract service interface. Mapping rules are defined to relate the interface description of the abstract service with the corresponding interface descriptions of the concrete services in the corresponding cluster (*abstract layer*).
3. *Categorization.* Finally, in this phase abstract services are associated to service categories; categories are organized in a standard generalization taxonomy and a domain expert defines association links between each leaf category in the taxonomy and one or more abstract services in the underlying layer (*category layer*).

After the application of these three phases, the obtained ontology is formally described according to XML-based languages and can be exploited to enhance the service discovery on the basis of user functional and non-functional requirements [5].

3 Future work

Future research activity will focus on the development of a tool environment for service discovery based on service ontologies for the semantic service description and the representation of semantic relationships among services. Service ontologies can be used for sharing knowledge on services and for service discovery. Relevant effort will be devoted to the development for ontology-based algorithms and techniques for matchmaking between service demands and service offers, and for dynamic service discovery.

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