Mediation Spaces for Similarity-Based Semantic Web Services Selection

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ABSTRACT
Semantic Web Services (SWS) aim at the automated discovery, selection and orchestration of Web services based on comprehensive, machine-interpretable semantic descriptions. The latter are, in principle, deployed by multiple possible actors (i.e., service providers and service consumers); thus, a high level of heterogeneity between distinct SWS annotations is expected. Therefore, mediation between concurrent semantic representations of services is a key requirement to fully implement the SWS vision. In this paper, the authors argue that “semantic-level mediation” is necessary to identify semantic similarities across distinct SWS representations. The authors formalize and implement a mediation approach based on “Mediation Spaces” (MS), which enables the implicit representation of semantic similarities among distinct SWS descriptions. As a result, given a specific SWS approach and the proposed MS, a general purpose algorithm is implemented to empower SWS selection with the automatic computation of semantic similarities between a given SWS request and a set of SWS offers. A prototypical application illustrates the approach and highlights the benefits w.r.t. current mediation approaches.

Keywords: Conceptual Spaces, Integration, Interoperability, Semantic Mediation, Semantic Web Services, Service Discovery, Web Services

INTRODUCTION
The increasing availability of a broad variety of Web services (WS) raises the need to automatically discover, select and orchestrate appropriate services for a given need. Current WS search engines or service registries (e.g., UDDI) mainly support simple keyword-based search on Web services based on syntactic descriptions such as WSDL. However, this rather syntactic paradigm does not support precise allocation of Web services partially because of the lack of semantics expressed in utilized service descriptions. Semantic Web Services (SWS) (Fensel, Lausen, Polleres, de Bruijn, Stollberg, Roman & Domingue, 2006) aim at addressing
this challenge on the basis of comprehensive, machine-interpretable semantic descriptions. Existing SWS frameworks, such as WSMO (WSMO Working Group, 2004) or OWL-S (Joint US/EU ad hoc Agent Markup Language Committee, 2004), enable the description of several WS-related functional (e.g. input and output, pre and post conditions, service choreography and orchestration) and non-functional (e.g. Quality of Service) parameters. However, since Web services usually are provided by distinct and independent parties, the actual WS interfaces as well as their semantic representations are highly heterogeneous. This strongly limits the interoperability and raises the need of mediating between semantic descriptions as well as the actual Web services interfaces. We can particularly identify two levels of mediation: semantic-level and data-level mediation. Whereas the former refers to the resolution of heterogeneities between concurrent semantic representations of services – e.g. by aligning distinct SWS representations of services equivalent in functionality – the latter refers to the mediation between mismatches related to the Web service implementations themselves, i.e. related to the structure, value or format of I/O messages. Therefore, semantic-level mediation primarily supports the discovery and selection stage, whereas data-level mediation occurs during service orchestration and invocation.

In this paper, we particularly address semantic-level mediation to support the WS selection problem. We argue that semantic-level mediation strongly relies on identifying semantic similarities between entities across different SWS ontologies (Qu, Hu & Cheng, 2006; Wu, Ranabahu, Gomadam, Sheth & Miller, 2007). However, semantic similarity is not an implicit notion within existing ontology representations. Moreover, automatic similarity detection as demanded by semantic mediation requires semantic meaningfulness. But the symbolic approach – i.e. describing symbols by using other symbols without a grounding in the real world – of established ontology representations does not fully entail semantic meaningfulness, since meaning requires both the definition of a terminology in terms of a logical structure (using symbols) and grounding of symbols to a conceptual level (Cregan, 2007; Harnad, 1999).

Despite the importance of mediation for widespread dissemination of SWS technologies, related approaches are still limited and underdeveloped (Paolucci, Srinivasan & Sycara, 2004). Current attempts to mediation usually foresee the manual development of rather ad-hoc one-to-one mappings or the application of ontology mapping methodologies, mostly based on identifying (a) linguistic commonalities and/or (b) structural similarities (Choi, Song & Han, 2006; Noy & Musen, 2003). Since manually or semi-automatically defining similarity relationships is costly, current approaches are thus not capable to support SWS selection within highly dynamic scenarios and at Web scale.

In our work, we investigate a similarity-based mediation mechanism in order to overcome the need for manual or semi-automatic formalisations of one-to-one mappings between distinct SWS representations. In this respect, we propose a general purpose mediation approach consisting of (a) a representational approach allowing to implicitly represent similarities and (b) a general-purpose mediator for semantic-level mediation, exploiting similarities as represented through (a). In particular, following the principles of Conceptual Spaces (CS) introduced by Gärdenfors in (Gärdenfors, 2000), we introduce the concept of Mediation Spaces (MS) to enable the implicit representation of semantic similarities across heterogeneous SWS representations through grounding of SWS descriptions into vector spaces. We demonstrate that refining heterogeneous SWS descriptions in multiple shared MS supports similarity-based mediation at the semantic-level and implicitly facilitates Web services selection.

The provided general-purpose mediator – implemented as a dedicated mediation Web service – is deployable for any semantic-level mediation scenario, when being used to support effective WS selection together with our proposed representational approach. For demonstration purposes, we currently deployed
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