Academic and Industrial Research:
Do their Approaches Differ in Adding Semantics to Web Services?

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Abstract. Since the new terms, "Semantic Web" and "Web services", have been introduced, researchers have followed two different roads. Following one road, academia has focused on developing a new set of languages to enable the automation of Web services execution and integration based on the Semantic Web. On the other road, industry has taken the lead to propose and develop technologies and infrastructures to support Web services and Web processes without, until recently, paying much attention to semantics. It is fundamental to analyze the trend that is being followed with regard to the "Semantic Web" and "Web services". Therefore, two important questions need to be answered: "do the approaches taken by academia and industry differ in how they add semantics to Web services?" and "are their efforts converging or diverging?" This paper, based on a panel discussion at an international conference on Web services, which consisted of members of both academia and industry, addresses precisely these two questions.

1 Introduction

In July of 2004, a panel was convened to consider a convergence or divergence between academic and industrial approaches to adding semantics to Web service and/or Web process descriptions. Everyone agrees that more semantics (or meaning) should be added to Web service descriptions. Differences results when the communities address the questions of how and how much. How much semantics? Should a Web service operation be given a full semantic specification, say using operational semantics [15] or would a functional classification or categorization suffice? How machine processable or understandable should the semantics be on the formality vs. informality scale? For example, a complete and formal semantic specification is difficult for humans to create or understand. A simpler agreement based approach predicated on standard interfaces (e.g., port types) may be a better short-term solution. It is also possible to move the standard back to an ontological level and then require the parts of a port type to map to an ontology. This approach to interoperability has proved successful in database integration (where each schema is mapped to a common ontology). One could expect similar success for Web services, yet the problem is more complicated since the description of operations is more complicated than description of data objects.

Given the importance and complexity of the issue (adding semantics), it makes sense that the academic and industrial approaches do differ. The industrial approach should be near-term, practical and with a high probability of success, while academia can afford to be long-term, ambitious and speculative. However, too much divergence may cause a fracture in which industry settles for too little and academia will design great things that will never be used.

In this paper, we briefly survey the current research and development occurring in academia and industry on Semantic Web Services (SWS). The panel consisted of researchers from both sectors and the paper strives for a balanced treatment highlighting the strengths of both approaches, analyzing their differences and seeking common ground for future work.

The paper is organized as follows: Section 2 reviews the brief history of attempting to provide semantics for Web services and relates this to the long history of attempting this for programs. Issues and directions are discussed as well as some aspects of current active research projects are highlighted. Section 3 parallel section 2, but from an industrial perspective. Because of the complexity of semantics, there are likely to be diminishing returns if too much is added (e.g., problems with intractability and undecidability as well as too hard to use). This section will start with the currently used standards for describing (WSDL 1.1) [22], publishing (UDDI 2.0) [19] and orchestrating (BPEL 1.1) [1] Web services and will consider how semantics are and will impact new (e.g., WSDL 2.0 [23] and UDDI 3.0 [20]) as well as future standards. Section 4 attempts to resolve the differing approaches into a recipe for long-term cooperation and success of this most vital new technological area. Finally, section 5 gives a brief summary of the most important aspects discussed in this paper.

2 Academic Research on SWS

Academic research into Semantic Web Services began with the work of DAML-S group [4]. The idea was to use a formal language to precisely define what a Web service does. A basic description along these line is provided by the Web Service Description Language (WSDL). WSDL descriptions are rather shallow and focus on operational aspects. As a consequence, these descriptions are inadequate for automated discovery or composition of Web services. Much richer and deeper machine-processable descriptions are therefore required. The DAML-S (now the OWL-S [13]) group added profile, process and grounding descriptions. A profile describes what the Web service does functionally in terms of input (I), output (O), precondition (P), and result (R), the process describes how it is built out of components and the grounding maps these to WSDL files. Much of the semantics is captured in the IOPR specifications.

A Web service, as a software component, has one or more operations that can be invoked as well as its own state. An operation may be described by indicating the types of its inputs and outputs, any preconditions required of the input as well as the results of the operation (either on the state or the outputs produced). Actually, this goal of specifying what an operation does or, in general, what a process does has a long tradition in Computer Science and includes work in the fields of program methodology, formal programming language semantics, software engineering and software agents. The problems are complex, but the potential payoff is great.

Besides the major OWL-S project, there are two ongoing projects being developed in the US, the LSDIS METEOR-S project, and in Europe, the DERI SWWS project.

The METEOR-S [14] (METEOR for Semantic Web services) project is focused on the usage of semantics for the complete lifecycle of semantic Web processes, which represent complex interactions between semantic Web services. The METEOR-S project targets research on four important areas of the lifecycle of semantic Web processes, namely, annotation, discovery, composition, and execution. For each of the research stages in the lifecycle a framework, infrastructure or environment has been developed and implemented. The METEOR-S semantic Web Service Annotation Framework (MWSAF) semi-automatically marks up Web service descriptions with ontologies. The algorithms developed match and annotate WSDL files with relevant ontologies. The METEOR-S Web Service Discovery Infrastructure (MWSDI) uses an ontology-based approach to organize registries, enabling semantic classification of all Web services based on domains. Each of these registries supports semantic publication of the Web services, which is used during the discovery process. The METEOR-S Web Service Composition Framework (MWSCF) enhances current Web process composition techniques by using Semantic Templates to capture the semantic requirements of the process [3]. The METEOR-S Web Service Dynamic Process Manager (MWSDPM) allows deployment-time and run-time binding of Web services to an abstract process, based on business and process constraints.

DERI [5] is currently working on a project titled Semantic Web enabled Web Services (SWWS). DERI researchers recognize that to use the full potential of Web services and the technology around UDDI, WSDL and SOAP, it is indispensable to use semantics, since current technologies provide limited support for automating Web service discovery, composition and execution. Important objectives of the SWWS initiative include providing a richer framework for Web service description and discovery, as well as, providing scalable Web service mediation middleware. Any necessary mediation would be applied based on semantic data and process ontologies and semantic interoperation.

Aside from investigations on functional descriptions of Web services, there are also work on behavioral descriptions (see [11]). The behavior signature [11] of a service describes how the service can interact with other services. Providing behavior signatures is critical in service composition. For example, the two interacting services may both wait for messages from each other and none of them can thus proceed [6, 7]. It has been argued that Web service composition, automated or semi-autmated, critically relies on the interaction patterns in the behavior specification [9, 10, 21, 2]. A tool WSAT was recently developed for analyzing conversations and Web service bahaviors [7].

3 Industrial Research and Development on SWS

The industrial research related to semantic Web services depends on the ongoing development of open standards that ensure interoperability between different implementations. Several initiatives have been conducted with the intention to provide platforms and languages that will allow easy integration of heterogeneous systems. The standardization efforts for the technologies that underlie Web services include Simple Object Access Protocol (SOAP) [17], Web Services Description Language (WSDL), Universal Description, Discovery and Integration (UDDI), and process description languages. Several process description languages have been proposed and studied by the industry.

These languages include W3C WS Choreography Group, Business Process Execution Language for Web Services (BPEL4WS, or simply BPEL) (from Microsoft, IBM, BEA), WSCL (from HP), BPML (from Microsoft), WSCI (from SUN, BEA, Yahoo, and other), XLANG (from Microsoft), and WSFL (from IBM).

The WSDL is already well established as an essential building block in the evolving stack of Web service technologies, and is being developed and standardized in the W3C's Web Services Description Working Group. WSDL is a specification to describe networked XML-based services. It provides a simple way for service providers to describe the basic format of requests to their systems regardless of the underlying protocol. WSDL is a key part of the effort of the UDDI initiative to provide directories and descriptions of such on-line services for electronic commerce and electronic business. WSDL does not, however, support the specification of processes composed of basic Web services nor it envision the use of semantics.

In this area, the BPEL4WS, currently has the most prominent status and enables defining business processes as coordinated sets of Web service interactions. The W3C's Web Services Choreography Working Group also has been chartered to explore this technical area.

All in all, there are few commercial products available that have successfully implemented a semantic layer alongside robust a Web services infrastructure, this despite significant industrial support which exists for standards such as WSDL, BPEL, and UDDI. As has been mentioned, there are two primary considerations for semantics with Web services - the process layer and the data layer. Most enterprise vendors have indeed recognized the importance and value of semantic metadata for each area, but tend to implement solutions in proprietary and brittle ways; using their own metadata formats for internal semantic reconciliation.

With regard to the process and orchestration semantics, many vendors seem to be taking a "wait-and-see" approach while the emerging standards converge. OWL-S, SWWS/WSML, and BPEL each have important strengths to add to an overarching semantic Web services capability. Leadership from DERI and the W3C have each expressed a strong interest in converging the best of each specification - vendors will no doubt wait for this alignment prior to implementing either on their own.

The hesitation shared by most commercial vendors will not be shared by many industrial research groups - IBM, HP, France Telecom, and Fujitsu have all applied semantics to Web services for innovative, discovery-driven use cases.

In contrast to "negotiation-style" semantic Web services, there are others who take a "query-driven" approach. In fact, some commercial vendors have begun implementing semantic layers on top of Web services as a way to issue queries to them instead of writing more brittle contracts. Annotating Web services using the W3C Web Ontology Language (OWL) can make it simpler evolve services in dynamic businesses. To do this, modeling tools map ontologies to Web service WSDL interfaces and a runtime inference engine issues query plans to the underlying services. This style of semantic query is clearly distinct from process-centric approaches, but both approaches help automate meaningful access to overly abundant corporate information.

4 Common Ground for Future Work

For Web services to become a platform for semantic service oriented computing, academic and industrial researchers will need to create terminologies, technologies, and products that enable sophisticated solution for the advertisement, discovery, selection, composition, and execution of Web services.

Recently, the Semantic Web Services Initiative (SWSI), an initiative of academic and industrial researchers has been composed to create infrastructure that combines Semantic Web and Web services to enable the automation in all aspects of Web services. In addition to providing further evolution of OWL-S, SWSI will also be a forum for working towards convergence of OWL-S with the products of the SWWS/WSMO [25]/WSML [24]/WSMX [26] research effort, which supplies Web service providers with a core set of constructs for describing the properties of their Web services in computer-interpretable form. OWL-S will facilitate the automation of Web service tasks, including automated Web service discovery, composition, and execution. The current version of OWL-S builds on the Ontology Web Language (OWL) recommendation produced by the Web-Ontology Working Group at the World Wide Web Consortium. OWL-S is the first well-researched Web Services Ontology, and has numerous users from the academia.

WSMO is a complete ontology for the definition of Semantic Web Services. It follows the WSMF as a vision of Semantic Web Services. WSMO itself is defined using an ontology language based on F-Logic [12]. It contains all concepts required for Semantic Web Services: Ontology, Mediator, Goal, Web Service Interface. The WSML is a family of languages that allow Semantic Web service designers to define Semantic Web services in a formal language. The WSMX provides a standard architecture for the execution of Semantic Web services. Its architecture is component-based and one possible implementation of Service-oriented Architectures. WSMX itself has execution semantics.

The largest patch of common research ground that industry and academia have to share is simple, or rather, making semantic Web services simpler. As with all semantic technologies, the rigor of expressing semantic Web services metadata (OWL, OWL-S, F-Logic, XML, etc.) with required precision is daunting without good tools. One day analysts will be dragging-and-dropping process diagrams and point-and-clicking ontology mappings. Until then, researchers in industry and academia would be well served to examine modeling heuristics to lower barriers for widespread adoption.

The more likely path of common ground will likely be to reach agreement on ontologies for service descriptions, processes, and security. At an even more fundamental level, researchers will have to measure the strengths and limitations of different representations such as description logics, horn-logic, and F-Logic for the erent layers of the semantic Web services architecture. In significant ways, the infusion of semantics will alter today's conceptions of the service-oriented architecture paradigm.

5 Summary

Many believe that a new Web will emerge in the next few years, based on the large-scale research and development ongoing on the Semantic Web and Web services. The intersection of these two, Semantic Web services, may prove to be even more significant. Academia has mainly approached this area from the Semantic Web side, while industry is beginning to consider its importance from the Web services side. Academia started developing semantic-based Web services languages, such as DAML-S (now OWL-S), to enrich the description of Web services to facilitate greater automation. The idea was to make explicit the representation of the semantics underlying data, services, and other resources, providing

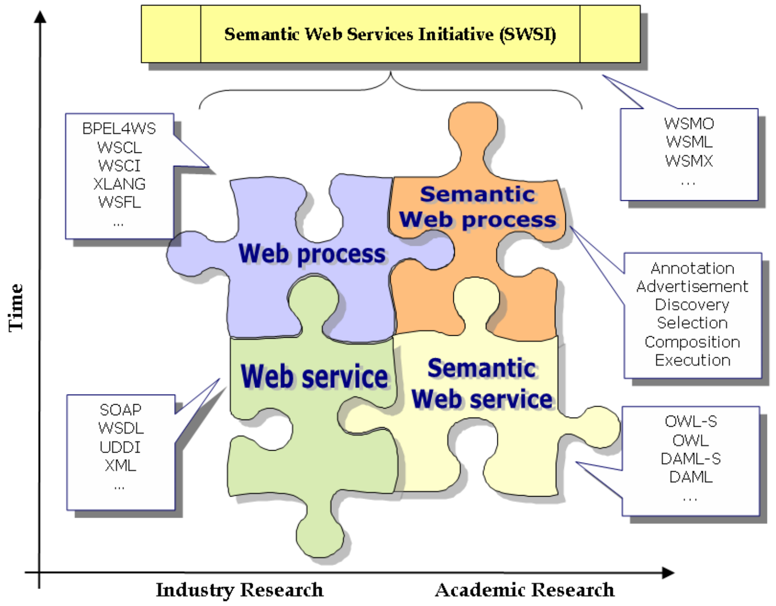

Fig. 1. Industry and academic research

a qualitatively new level of service. Industry was interested in developing an infrastructure that could allow software applications to be accessed and executed via the Web based on the idea of Web services. Their efforts resulted in important, practical, and functional standards such as UDDI, WSDL, SOAP, XLANG, WSFL, WSCI, BPML, BPEL4WS, etc. While the two approaches can be seen as being parallel, recently their is some area of convergence. Both academia and industry have realized that for the sake of automation and dynamism in all aspects of Web services provision, it was indispensable to create an infrastructure that combines, at least to some extent, Semantic Web and Web services technologies (Fig. 1). This paper has highlighted some of the contributions of both industry and academia and discussed recent cooperative efforts such as SWSI. Semantic Web Service technology's potential impact makes it essential for further and expanding cooperative efforts to be pursued in the future.

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