World-altering Semantic Web Services Discovery and Composition Techniques - A Survey

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Abstract— *Semantic Web services evolved from traditional computational services by semantic descriptions. Recently, there have been many research efforts in the field of semantic Web services, which reveals enormous potential for Service-Oriented Architecture to be promoted to an improved architecture. However, world-altering services have been largely disregarded because of the limited facilities in current description languages to express required conditions. Enterprise Application Integration systems need world-altering services because most of the business services need preconditions to be held prior to their service execution. Moreover, they generate effects, both of which must be contemplated in the service environment. To exploit the semantic Web services in reality, efficient discovery and composition approaches need to be developed to complement the service environment requirements. This paper intends to overview selective methods for discovery and composition of world-altering semantic Web services.*

Keywords: Semantic Web Service, Discovery, Composition, World-altering Action, Precondition, Effect

1. Introduction

Service-Oriented Architecture (SOA) describes the abstract concept of interaction between the *service provider* and the *service consumer* through provision, discovery, and usage of services over the Internet. The provider introduces the core functionality (service interface) that will be utilized by requesters. The term "service" will be used henceforth to refer to the software engineering community, i.e., the computational parts of concrete services. The business community, on the other hand, designates the whole process, including actual interactions, as a service.

Service descriptions are published in a repository arranged by a third participant of SOA, called the *service broker*. The service broker also mediates negotiations between providers and consumers [1, chap. 2]. This mediation commences early on, particularly during **discovery** of the consumer's desired service. The mediator may also **compose** several services when prevailing atomic services are incapable of complying with the requester's demand. Currently, service brokers propose various **failure recovery** mechanisms (such as [2]) to provide resiliency for composition and execution tasks.

This paper explains selective approaches to service discovery and composition. The remaining sections give details on current discovery and composition techniques that explicitly consider world-altering services. Section 2 introduces semantic Web services, a categorization of services based on their actions, and a classification of their effects. Section 3 briefly presents some approaches to discovery and matchmaking of services. Section 4 gives an overview of exclusive service composition methods. The paper concludes with future plans in the final section.

2. Semantic Web Services

"Semantics" describes the formal meanings of functional and non-functional behaviors of services. Semantic Web services supplement traditional services with semantic specifications. The syntactic specification (WSDL[3]) employed by current practical services hinders automatic mediation at runtime. A study carried out by Lu et al. [4] shows that there are few actual services annotated by semantics, implying that semantic Web services were disregarded in the empirical study. Nevertheless, collections of semantic Web services are not difficult to find. SWS-TC, generated manually by Ganjisaffar and Saboohi[1], contains 241 semantic Web services, mostly real Web services. Additionally, OPOSSum[2][5] assembles data from SWS-TC and others to create an assemblage of *semantic Web services* (SWS) with different description languages – it presently contains over 1500 services [6].

Despite the creation of these collections, there are not enough semantically annotated services (in contrast with a very large, indeterminate number of existing services described syntactically) to accommodate requesters' needs, especially when requests are complex.

2.1 Service Actions and Terminology

There are two categories of services: *information-providing* and *world-altering* [7].

[1]Semantic Web services' test collection available at
`http://www.semwebcentral.org/projects/sws-tc/`

[2]Online portal for semantic services available at
`http://fusion.cs.uni-jena.de/OPOSSum/`

Information-providing services (also known as "information-generation" or "information-gathering" in the literature) are services that produce or gather information and generate *output*, usually based on *input* provided by the requester (i.e., they return information regarding the user's request).

From the agent's perspective, *information-providing services* have actions that only change the knowledge of the agent. These services sometimes require specific world states or conditions (called *preconditions*) to be held preceding their execution initiation time. These conditions are evaluated with respect to the client's environment before execution of the action [8] and guarantee the successful accomplishment of the services.

However, **world-altering services** (also known as "world transition") change the state of the world by their execution. In other words, thorough execution of the operation delivered by a service produces some valid facts about the world. This type of service can also have input, output, and preconditions. Moreover, world-altering services produce *effects* (the new state of the world) after their execution.

Finally, service descriptions may have a *post-condition* that identifies the input-output relationship along with conditions, both of which are evaluated in the server context [8] and guaranteed to be held over the output.

World-altering actions are used in ubiquitous (pervasive) computing, business-related services, interoperability among systems, and Enterprise Application Integration (EAI).

Sirin categorizes service effects as **world-altering effects** and **knowledge effects** [9]. In general, world-altering service actions and their accomplishment effects can arguably be classified as belonging to three families:

1) Service actions altering concrete objects in the world, such as shipment of products to customers.
2) Series of activities modifying "compensable information changing," such as data manipulation in a database.
3) Operations affecting "non-compensable information," such as accepting payment by credit card.

There are various semantic Web services' description languages declared by different groups with distinctive objectives. These languages include but are not restricted to OWL-S [10], [11] (formerly known as DAML-S[3]), WSML [12], SAWSDL [13], and DIANE [14], [15]. In this paper, we will presume some familiarity with these languages, hence their lack of presentation. This work is not restricted to any formalism, and all major languages have been investigated.

OWL-S is one of the major efforts to annotate services. In their latest release (1.2) [16], OWL-S Coalition added some other possible languages for indicating different conditions of services as compared with the previous releases. OWL-S now allows that preconditions and effects to be expressed in logic languages like KIF [17], DRS [18], SWRL [19], RDQL [20], and SPARQL [21].

WSMO (Web Service Modeling Ontology) [22] defines a model to describe semantic Web services, based on the conceptual design set up in the WSMF (Web Service Modeling Framework) [23]. Successive to the key aspects noticed in the Web Service Modeling Framework, WSMO distinguishes four top-level elements as the main concepts: Ontologies, Web services, Goals and Mediators. Moreover, WSML (Web Service Modeling Language) as a formal language is used to describe ontologies and Semantic Web services. WSML contains all aspects of Web service descriptions pinpointed by WSMO.

SAWSDL is evolved from WSDL-S [24] and takes a bottom-up approach, building on top of WSDL [25]. SAWSDL is the only semantic Web Service language which is a W3C Recommendation and even other major ones are still Member Submissions.

DIANE will be presented separately in the "Discovery and Matchmaking" approaches (Section 3).

2.2 A Survey

a) Problem Statement: In the literature, although there are thousands of approaches for discovery and composition of semantic services, most of them ignore the world-altering services and just use information services, due to factors such as simplicity or inefficiency of service description languages for expressing service pre/post-conditions and effects.

b) Significance of study: Considering preconditions and effects of services is crucial in various aspects of mediation. Different services may have the same input and output types and categorically diverse operations semantics [8].

To find appropriate atomic services or to construct them to generate a valid composition, services' preconditions and effects specifications help to a better ranking of candidates or a choice of the most accurate service.

Furthermore, to recover a service-based software application in case that a failure occurs, the mediator needs to undo service execution effects using "compensation needs" specified in service description even by calling another service to perform the restoration to the previous conditions.

Obviously, service discovery, composition, and failure recovery need to be done in an automatic manner. This need is due to increasing number of Web services, especially semantic Web services, emerging in today's computing world. Approaches such as [26] claim the finding of services by their preconditions and effects are not necessary by proposing the concept of manual tagging of services cannot help.

[3]DARPA agent markup language for services, `http://www.daml.org/services/daml-s/2001/05/`

3. Discovery and Matchmaking

Semantic service mediation begins with the finding of demanded service to carry out actual functionality. The user specifies the requirements, and a mediator tries to match them with a service description by a service matchmaking algorithm. Two closely related approaches use the algorithm. The matchmaking algorithm usually starts with situating a fully conformed service to the user's requirements based on capabilities. If such a service does not exist, the algorithm can identify all relevant services to construct a valid solution (cf. to Section 4) to fulfill the user's goal [27].

Matchmakers usually consider just inputs and outputs of services. Functional semantics, preconditions and effects of the services have to be regarded to find fully matched services. There are different services that have the same inputs and outputs, but with unrelated functionalities. Besides, other important, non-functional properties of services, such as quality of service, should be considered as well.

Authors in [28] argue that, in various aspects of service mediation, especially in Enterprise Application Integration (EAI), preconditions and effects must be scrutinized. They have fostered an extended matchmaking algorithm. This algorithm is used in the composition process of semantic Web services to pick out concrete services and substitute them instead of abstract sub-tasks. The extension adds preconditions and effects of service descriptions to the matching process as well as matching rules.

One point that is neither discussed nor even explicitly cleared in [28] is the way of finding the final degree of match of services. As [27] proposes, resulting matches are scored and sorted. Then the headmost service will be given to the requester. Adding preconditions and effects properties of services to inputs and outputs for matchmaking algorithm should clearly be stated as to how it affects this degree of match.

Pessoa et al. state in their recent survey [29] that, in the composition approaches studied, among all, METEOR-S [30] annotates service descriptions with preconditions and effects. Then these descriptions are used in service matching and selection, particularly in ranking of services.

Furthermore, MoSCoE [31] which uses OWL-S as service description language, considers preconditions and effects in addition to inputs and outputs in service discovery.

WSMF [23] also considers pre/post-conditions and effects in service description and dynamic binding of services at the runtime.

Authors of [32] propose a solution to discovery problems of *SWS-Challenge*[4]. They present DIANE Service Description (DSD) [15] as a language for describing semantic Web services along with a related matchmaking algorithm. The language is equipped with world-altering operations with one or more effects by various suggested elements, such as *operational elements* and *aggregational elements*.

One problem of DIANE is that there are not publicly available service descriptions in this language.

Authors of [33] present a precondition- and effect-enabled matchmaking algorithm for Web services using satisfiability checking of $\mathcal{SHOIN}^{+}(\mathbf{D})$ description logic reasoner. The algorithm's complexity claimed to be NExpTime-complete.

The approach presented in [34] proposes to use various degrees of matching for preconditions and effects along with input and output. They claim that the language which is possible to use for precondition and effect descriptions can be any of KIF [17] and PDDL [35]. They add the degree of matching of preconditions and effects, one level below the degree of matching of input and output. To match conditions between advertised conditions and queried conditions they define three phases. These phases include Parameter compatibility, condition equivalences and condition evaluation. For comparison purpose, they use both the concepts in conditions and operators.

One thing that is not clear in [34] is the translation method of preconditions and effects. In the OWLS-TC version they seem to use, there is no formal description of preconditions and effects, so they may translate the informal description of preconditions and effects and then use them in their algorithm. This is not specified in their experimental results. The way in which they interpret the operators for conditions is unclear as well.

In [8], authors propose the use of RDQL for services' preconditions and results descriptions. RDQL was a W3C submission[5] for RDF [36] data query language[6]. The goal (agent's goal) is also represented using RDQL query. Authors propose use of case reasoning for checking of applicability of the result. Results are claimed to be checked in the context of server and not the agent. They assume that the service is executed and that the results are available. Then they infer that the result conditions are true and add this new knowledge to the knowledge base and check the satisfiability of the goal. Therefore, the usefulness of the service is checked. Their focus is on *information providing* services, but because of the use of results (effects), the approach is also applicable to *world-altering* services.

The authors of [8] later evolved their work to [37] using SPARQL instead of RDQL. The approach is based on the use of SPARQL as the expression language of semantic Web services described in OWL-S. Preconditions, result conditions, and effects of OWL-S are modeled by SPARQL query forms[7]. The query form returns a RDF graph which describes the new world's state following process execution.

[4] Semantic Web Service Challenge: Evaluating Semantic Web Services Mediation, Choreography and Discovery (http://www.sws-challenge.org/)

[5] `http://www.w3.org/Submission/RDQL/`

[6] RDQL is now obsolete and replaced by SPARQL[21]. SPARQL is now a W3C Recommendation for RDF data query language

[7] They suggest the usage of SPARQL CONSTRUCT query form for a process result.

They claimed that the advantage of using SPARQL for this matter is the compactness of definitions of the process results and agent's goal. This effort primarily regards information services; however, they claim its applicability to world-altering services.

Authors of [38] used the same approach as [37] for SAWSDL description languages regarding service conditions and agent's goal. They have classified four semantic modeling aspects, namely Functional Semantics, Data Semantics, Non-functional Semantics, and Behavioral Semantics.

Bener et al. [39] proposed a matchmaking architecture to match Web services based on input and output descriptions and preconditions and effects rules. They have used SWRL as annotations for preconditions and effects. A test collection of 100 services described in OWL-S, including precondition and effect annotations in SWRL, has been created, and the architecture has been evaluated by 20 test queries. The result shows better precision at different recall levels for input, output, precondition, and effect matching in comparison with only input and output matching.

Authors in [40] use precondition and effect specifications equally with input and output signatures in their discovery approach. They use logical formulas for preconditions and effects. They claim that the approach is not restricted to any formalism. The language they have used for their implementation is WSML. The idea is to use different formalism for describing service offers and requests.

Therefore, matchmaking algorithms trying to find any functional match that satisfies user's specified goal need to take into account pre/post-conditions and effects of services, along with inputs, outputs, and non-functional properties such as quality, cost, or security.

4. Composition

Service composition generates a structure containing existing services and correlates them based on outputs, post-conditions, and effects of one service to inputs and preconditions of another service respectively. These services comprise the needed functionalities of the so-called composite service.

Composition approaches are differentiated as manual, semi-automatic, and automatic. Moreover, another characteristic of composition methods is binding time of actual constituent services, which can be static binding or dynamic binding.

As previously stated, in all subtasks of service composition, accounting for the specific features of world-altering services, like their preconditions and effects, is crucial in achieving a proper composed service.

Shin et al. [41] claim that, without specifying preconditions and effects of services, composers are unable to generate the correct service compositions, so functional semantics of services have to be respected.

In [42] authors use SWRL to represent functional properties, i.e., inputs, outputs, preconditions, and results, of services in OWL-S. Their study implies an encoding method of OWL-S atomic processes to semantic Web rules and SWRL, as well as use of them in a composition algorithm.

Hristoskova et al. in a recent study [43] introduce a Dynamic Composer, which constructs a service composition by matching preconditions of a service to effects of the previous service in a composition structure. This matching is claimed to be done similar to input-output matching. The Dynamic Composer also uses the approach in [37] to translate preconditions and effects to SPARQL.

Many publicly published research papers have been studied to investigate the capabilities of their proposed composition methods that use world-altering services. Among all, techniques shown here declare their approach to support both world-altering and information-providing services.

5. Conclusion

To the best of our knowledge, this is the first survey on discovery and composition of semantic Web services that clearly indicates world-altering category of services. In recent years, excessive researches have been conducted on the field of semantic Web services, but most of them only use information-providing services and ignore the existence of world-altering actions.

We are still investigating other published systematic ways to find existing world-altering semantic Web service discovery, composition, invocation, and monitoring and failure recovery methods. At the same time, evaluation of all recognized strategies is being conducted.

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