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An Approach to Evaluate and Enhance the Retrieval of Web Services Based on Semantic Information

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1 Research Problem

Web services have the potential to be composed to cross-organizational workflows. Due to their loose coupling, Web services provided by internal and external parties can be integrated into workflows at runtime. This vision aims for dynamic ad hoc collaborations between different business partners and entities.

In order to achieve the (semi-) automatic composition of Web services to business processes and workflows, it is necessary to identify the appropriate services. Unfortunately, a syntactic description of a Web service's capabilities is sufficient only if all potential parties (i.e., service providers, service brokers, and service requesters) use the exact same vocabulary. However, this is quite unlikely even in a corporate environment. Therefore, it is necessary to enrich Web service descriptions with semantic annotations and use them in the discovery process.

Even though the retrieval of Web services based on semantic information has already been investigated in several approaches, differences in Web service standards and the repositories used for the evaluation of these approaches has led to both a lack of in-depth evaluations and comparability of the proposals. Until now, surprisingly little effort has been put into the measurement of semantic Web service (SWS) retrieval performance.

Nevertheless, in order to identify the "best of breed"-approach to SWS retrieval it is necessary to have the means to compare the different approaches. Subsequently, it is possible to enhance or combine current techniques in order to improve retrieval results. The different methods for SWS retrieval should be evaluated at least regarding computation time and measures to identify the quality of results, i.e., precision and recall.

2 Related Work

SWS retrieval is based on a matchmaking engine, i.e., an algorithm that finds the best fitting Web services for a precise service request. There are no limitation

regarding how this algorithm is actually implemented, the form of the request, the number and the sequence of "best fitting" services, or which service feature is retrieved. Several authors have proposed different kinds of matchmaking based on the degree of conformity between the requests and Web service descriptions. In most cases, service requests are expressed as Web service descriptions that perfectly meet the requests; a query in terms of keywords or the ability to browse a service repository are not provided. Hence, it is necessary to identify the inputs and outputs of the Web service which fits perfectly, thereby making it more difficult for uninformed users to find appropriate services.

An obvious approach to SWS matchmaking has been proposed, i.e., by [8] and [5] with the matching of capabilities: A service is deemed to be of use for a requester if all outputs requested are matched by the outputs advertised and if all inputs needed by the service advertised can be covered by the inputs provided by the requester. Matches between inputs/outputs requested and advertised are categorized into *exact*, *plug in*, *subsumes*, and *fail* matches [5]. Thus, it is possible to arrange services by the degree to which they match the inputs/outputs requested.

The four categories mentioned may also be employed to measure the degree to which an advertised Web service can meet a request. A detailed implementation of this approach is presented in [4]. The authors enhance the four mentioned categories by *intersection*. However, it is not possible to assess, for example, which of two *plug-ins* better meets a request. Xu et al. propose the use of semantic distances between concepts in an ontology which extends this categorization and introduces a feasibility to rank Web service [9]. Klusch et al. enhance the frequently applied logic-based approaches with content-based information retrieval [1].

Regarding the evaluation of approaches to SWS matchmaking, most researchers fall back on their own Web service data sets. Consequently, this constrains the ability to compare evaluation results. To overcome this issue, the research community has come up with different contests in which researchers can bring in their approaches for such evaluations.

The *S3 Matchmaker Contest* adopts the OWLS-TC2 test data set [2]. As its name implies, this constrains the deployment of Non-OWL-S algorithms. Even though OWLS-TC2 can be regarded as a state-of-the-art test data set at the moment, it lacks real world examples and the semantic richness of Web services [3]. It is planned to include WSDL-S/SAWSDL and WSML test data sets and approaches in the next executions of this contest, but even then it would "only" be possible to compare one SAWSDL-based approach to another SAWSDL-based approach etc.

The *Semantic Web Service Challenge* is currently the most established contest and has been carried out several times since 2006. Its aim is to develop a test bed for different matchmaking frameworks. Hence, this contest is independent of Web service standards. All services are only specified by natural language descriptions and hence must be adopted to the matchmaking approach at hand [6].

3 Expected Contributions

The contributions of my thesis include both an evaluation workbench that covers the issues regarding evaluation approaches currently used and the evaluation of a heuristic-based algorithm for SWS matchmaking.

The approaches presented to SWS matchmaking evaluation lack at least *one* of the following issues (a detailed discussion of the pros and cons of these contests is presented in [3]):

- Lack of real world example Web services
- A too small set of Web services
- Some meaningful evaluation criteria are not examined
- Limitation to one Web service standard
- Results are often not published in detail, i.e., the actual retrieval results per query etc. are missing in the concerned publications
- Degree of matching is only of subordinated importance

While it is very difficult to address the first two issues without contributions from a large community, it is possible to counter the remaining problems. Hence, the implementation of the workbench in my thesis is based upon the following principles:

- Provision of a Web-based workbench for SWS matchmaking algorithms which can be used by the research community.
- Requests may be expressed in different Web service languages.
- Answer sets are not constrained by the language of existing Web services.

It must be noted that it should not and cannot be the aim of the proposed workbench to replace the well-established contests mentioned above. Quite on the contrary, the goal is to provide researchers with another possibility to evaluate SWS matchmaking algorithms, especially the approaches to SWS matchmaking in our working group.

Current approaches to SWS matchmaking which do not take their performance into account are hardly feasible in dynamic real-time scenarios due to the large number of potential Web services involved. This is especially complicated if a workflow has to be replanned at runtime. In such a case the computation time of a composition becomes crucial. Hence, it is necessary to find the appropriate Web services in a very short period of time. Replanning at runtime becomes necessary, if the Web services chosen at design time are not available anymore. Obviously, a service consumer is not willing to wait for the transaction of a predefined functionality or workflow. Thus, it is necessary to identify and make use of other possibilities to minimize the retrieval time for Web services.

This leads to an optimization problem based on the objective function and constrains which have to identified. Instead of using time-consuming linear integer programming, I propose the usage of heuristics in order to minimize computation time.

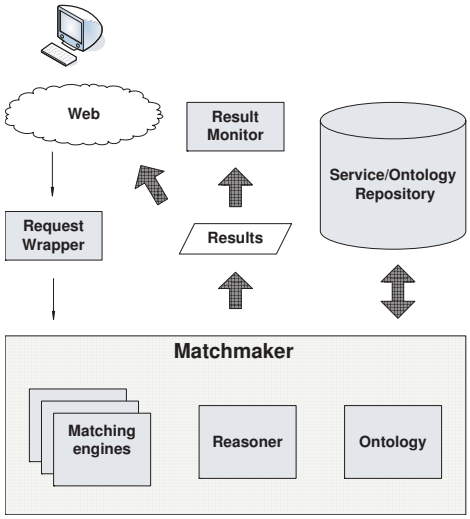

Fig. 1. Overview of Evaluation Workbench SEM.KOM

4 Next Steps

A prototypical implementation of the evaluation workbench has already been carried out in SEM.KOM (cp. Fig. 1 and [7]). Although the capabilities of this workbench are permanently enhanced, we have not yet implemented all possible features of SEM.KOM. In particular, it is necessary to include more retrieval approaches and Web service standards.

Currently, the components illustrated in Fig. 1 have been realized as follows:

- The *request wrapper* uses a RDF/XML format to convert the service request into a comparable format. It is possible to use a keyword-based search or to post the request in terms of a complete OWL-S description. The *Jena Semantic Web Framework* (version 2.5.4) is used to read and write RDF- and OWL-statements. In order to parse OWL-S, we use OWL-S API 1.1.0 beta (`http://www.mindswap.org`).
- It is possible to choose from two approaches of SWS retrieval (*matching engines*): the implementation of either logic-based reasoning as presented in [8] or keyword-based search. A combination of these approaches is also provided.
- The *service repository* is available in the form of files in a directory and can be accessed via an interface which wraps all the services advertised. At the moment, we are deploying OWLS-TC (version 2.2 [2]) as the dataset for testing.
- The *result monitor* provides the quality metrics precision, recall, F1 score and average query response time and stores them and all corresponding metadata.

In the near future, the following steps will be performed:

The Workbench will be enhanced by more service wrappers in order to support SAWSDL-based service requests. Furthermore, it is planned to provide the workbench via a website or as a Web service. One further long-term objective could be the provision of an ontology-based GUI which allows for the browsing of services.

The Heuristics have to be (mathematically) derived, implemented and evaluated both within SEM.KOM and in the contests mentioned in Sect. 2. Furthermore, the heuristics should be able to deal with incomplete semantic information.

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