IMPROVED SERVICE RANKING AND SCORING: SEMANTIC ADVANCED MATCHMAKER (SAM)

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Keywords: Matchmaking, semantic similarity, scoring, ranking, OWL-S, bi-partite graph, scoring, semantic distance.

Abstract: In recent years Semantic Web has drawn a lot of attention in order to solve the problem of automatic discovery and processing of web services. Although there are different efforts and frameworks for semantic annotation and discovery of web services, they mostly classify the discovered web services as set-based. Improvement in matching process could be gained by the use of ontological information in a useful form. The goal of this research is to propose a more accurate discovery method using the ontological distance information defined and ranked by users. In this paper, we focus on one of the most challenging tasks in service discovery: matchmaking process. We use an efficient matchmaking algorithm based on bi-partite graphs. Our proposed algorithm uses attribute ranking through weight assignment. Our experiment results show that bi-partite matchmaking has advantages over other approaches in the literature for parameter pairing problem. We present value added approaches in matchmaking such as property-level matching, semantic distance information and WordNet scoring. The value added approaches provide better scoring scheme and allows similarity to be captured resulting in ranking of services according to their relatedness.

1 INTRODUCTION

In recent years, web services became the dominant technology in providing the interoperability among different systems throughout the web. The problem of finding the right and most suitable web services for user needs emerges when open e-commerce systems are widely used and user requirements dynamically change over time.

Although there are currently proposed technologies for discovery of web services, such as UDDI (http://www.uddi.org,, 2006.), they do not satisfy the full discovery requirements. This discovery process is based on syntactical matching and keyword search that does not allow the automatic processing of web services. To solve the problem of automatic discovery and processing of web services, the Semantic Web (http://www.w3.org/2001/sw/, 2006.) as a new vision is proposed. The Semantic Web is an effort by the W3C consortium (http://www.w3.org/, 2006.), and one of its main purposes is to facilitate the discovery of web resources.

There are different efforts and frameworks for semantic annotation and discovery of web services (Motta, E., J. Domingue, L. Cabral and M. Gaspari, 2003, Fensel, D. and C. Bussler, 2002). For web service discovery they also propose some techniques and algorithms. However, they mostly classify the discovered web services in set-based approaches. They do not focus on rating the web services using semantic distance information (Klein, M., B. Konig-Ries and M. Muussig, 2005).

The evolution of web services, from conventional services to semantic services, caused service descriptions contain extra information about functional or non-functional properties of web services. The semantic information included in the service descriptions enables the development of advanced matchmaking schemes, capable of assigning degrees of match to the discovered services. Semantic discovery of web services means semantic reasoning over a knowledge base, where a

S. Ilhan E., B. Akkus G. and B. Bener A. (2007).
IMPROVED SERVICE RANKING AND SCORING: SEMANTIC ADVANCED MATCHMAKER (SAM).
In *Proceedings of the Second International Conference on Evaluation of Novel Approaches to Software Engineering* , pages 95-102
DOI: 10.5220/0002586700950102

goal describes the required web service capability as input. Semantic discovery adds accuracy to the search results in comparison to traditional Web service discovery techniques, which are based on syntactical searches over keywords contained in the web service descriptions (U. Keller, Lara R., Polleres A, 2004).

Improvement in matching process could be gained by the use of ontological information in a useful form. With the use of this information, it can be possible to rate the services found in discovery process. As in real life, users/ agents should be able to define how they see the relation of ontological concepts from their own perspective. Similarity measures have been widely used in information systems (Voorhees, E, 1998, Ginsberg, A., 1993, Lee, J., M. Kim and Y. Lee, 1993), cognitive science, software engineering and AI (Agirre, E. and G. Rigau, 1996, Hovy, E., 1998, Wang, Y. and E. Stroulia, 2003). So integration of knowledge from these techniques can improve the matching process.

By using semantic distance definition information, we aim to get a rated and ordered set of web services as the general result of the discovery process. We believe that this would be better than set-based classification of discovered services. In this paper, we propose a new scheme of matchmaking that aims to improve retrieval effectiveness of semantic matchmaking process. Our main argument is that conventional evaluation schemes do not fully capture the added value of service semantics and they do not consider the assigned degrees of match, which are supported by the majority of discovery engines. The existing approach to service matchmaking contains subsumption values regarding the concept that the service supports. In our proposed approach, we add semantic relatedness values onto existing subsumption-based procedures. We introduce value added approaches to matchmaking process such as property-level matching, semantic distance information and WordNet scoring. Property-level matching provides capturing similarity between concepts that do not have a subsumption relation. So that, services that would not be classified, are ranked with our matchmaking agent. Similarity distance provides user's profile to be represented in the ontology. Similarity distance weights can be assigned on the links between concepts to specify concepts relatedness to each other in an explicit way. Also by making use of WordNet, we introduce a second source of semantic repository to be utilized in matchmaking. Our test results in section 5 indicate that these value added approaches increases the captured semantic relations between parameters of services and provide a better ranking of services resulting in better user experience in matchmaking.

2 RELATED WORK

Semantic Web services aim to realize the vision of the Semantic Web, i.e. turning the Internet from an information repository for human consumption into a worldwide system for distributed Web computing (http://www.w3.org/2001/sw/, 2006.). The system is a machine-understandable media where all the data is combined with semantic metadata. The domain level formalizations of concepts form up the main element within this system, which is called ontology (http://www.w3.org/Submission/OWL-S, 2004). Ontology represents concepts and relations between the concepts; these can be hierarchical relations, whole-part relations, or any other meaningful type of linkage between the concepts(H. El-Ghalayini, M. Odeh, R. McClatchey, and T. Solomonides,, 2005).

The semantic matchmaking process is based on ontology formalizations over domains. In the upcoming section we present some of the selective research on the matchmaking process considering the concepts that we build our research on. Matchmaking of Web services considers the relationship between two services. The first one is called the advertisement and the other is called the request (Klusch, M., Fries, B., Khalid, M., and Sycara, K.. 2005). Advertisement denotes the services description of the existing services while the request indicates the picture of service requirements (Wang, Y. and E. Stroulia, 2003).

In (Wang, H., Zengzhi L., Fan L., 2006), the problem of capability matchmaking is analyzed with regarding to Web services, especially the Preconditions and Effects (PE) matchmaking. In the paper, the authors present a service similarity function that determines similar parameter classes by using a matching process over synonym sets, semantic neighbourhood, and distinguishing features. Parameter pairing is the process that is used for matching service descriptions. In the work, maximum weight bi-partite graph matching method is utilized for parameter finding; the weights of bi-partite graph's edges are evaluated with matching degree between function parameters calculated by the similarity function mentioned above.

Although good results are obtained with the usage of this method, it should still be improved in two terms: One is that, it needs to be extended on pre-condition and affect because the matching is performed only on parameters of input and output, and the functional signature is not sufficient to identify what it does. The other is that this framework should be combined with particular directory service like UDDI in order to improve the discovery efficiency.

In (Paolucci M.; Kawamura,T.; Payne,T. and Sycara,K. , 2002) the authors present an algorithm that deals with the localization of Web services. The research does not address the interoperability problem. The system introduced uses the service profile ontology from the DAML-S specification language but only considers the matching of input and output concepts defined by the same ontology.

Traditional approaches to modelling semantic similarity between Web Services compute subsume relationship for function parameters in service profiles within a single ontology. In (Ruiqiang Guo, Dehua Chen, Jiajin Le, 2005) a graph theoretic framework based on bi-partite graph matching for finding the best correspondences among function parameters belonging to advertisement and request is introduced. On computing semantic similarity between a pair of function parameters, a similarity function is introduced, determining similar entity, which relaxes the requirement of a single ontology and accounts for the different ontology specifications. The function presented for semantic similarity across different ontologies provides an approach to detect similar parameters. The method is based on a matching process over weighted sum of synonym sets, semantic neighbourhood, and distinguishing features. The method mainly lacks use of functional similarities and lexical evaluation of semantic mappings.

In (COMPSAC, 2006), a semantic ranking MSC is designed to rank the results of advertisements matchmaking. MSC stands for the initials of three factors' second words: Semantic Matching Degree (to capture the semantic aspects of attributes), Semantic Support (to describe the interestingness or potential usefulness of an attribute) and Relational Confidence (to capture the association relationships among attributes). Three categories of attributes are defined in advertisements matchmaking: *Generalizable Nominal Attribute (GNA)* whose values can form a concept hierarchy; *Numeric Attribute (NUA)*, called quantitative attribute, whose values are numeral; Nominal Attribute (NOA) whose values are neither numeral nor can form a concept hierarchy. Three new factors are designed to capture the semantic characteristics and relationships of the attributes: Semantic Matching Degree, Semantic Support and Relational Confidence.

3 PROBLEM STATEMENT

The first step in service composition is identifying the domain of interest by means of taxonomy of subject categories. The discovery and selection of services those are suitable for a given request is obtained in two phases. Firstly, matchmaking approach is based on the ontological framework. It is applied on the set of available services in order to find services that match needs of the requestor from a functional point of view. Secondly, services are ranked and further refined. This is done by taking into account context information of the requestor. Then preconditions or post-conditions can be defined as mandatory or optional.

The problem that we are concerned is the first step of this scenario: given a request *r*, finding right web services for *r*. The main goal of this research is to gain better precision and recall values on matchmaking by considering user requests in web services discovery.

The previous work on semantic matchmaking focused on taking advantage of a single implementation based on some information retrieval theory. The experimental research so far has shown simple subsumption based matchmaking is not sufficient to capture semantic similarity.

In this research, we aim to provide an efficient and accurate matchmaking algorithm using scoring and ranking based on similarity distance information, extended subsumption and property level similarity assessment in a general semantic web service discovery framework.

4 PROPOSED SOLUTION

In this paper we propose a hybrid approach on semantic matchmaking. Our proposed solution uses decision modules that can be plugged in and out. We have implemented some of these modules to add semantic relatedness values onto existing subsumption-based procedures. Our proposed matchmaker agent mainly provides ranking and scoring based on concept similarity. The components of the proposed system are shown in Figure 1. Request service definition and the corresponding relevant services set, which are discovered through conventional discovery mechanisms, are presented as input to the system. The ontology and services we use are retrieved from "OWL-S Service Retrieval Test Collection version 2.1". The services in the collection are mostly extracted from public UDDI registries, providing

582 web services described in OWL-S from seven different domains. The OWL-S Test collection version 2.1 contains 29 queries, each of which associated with a set of 10 to 15 services (Mahboob Alam Khalid, Benedikt Fries, Patrick Kapahnke, 2006). We extended some ontologies in this test collection for our own purposes in order to better demonstrate the features of our proposed matchmaking agent. We believe that a formal test collection of OWL-S services is crucial for the evaluation of matchmaking agents.

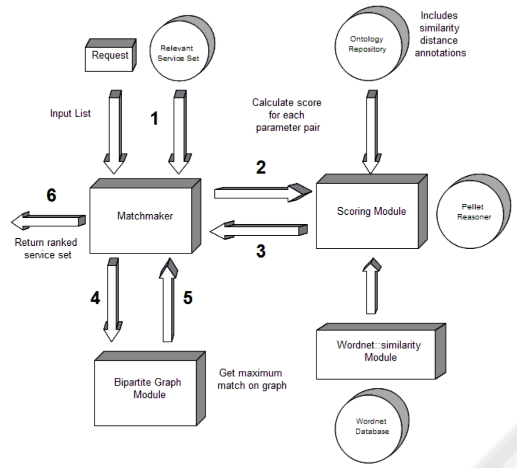

Figure 1: Matchmaking agent components.

The main software components of our proposed matchmaking agent are shown in Figure 2. The top layer represents our matchmaker SAM (Semantic Advanced Matchmaker). OWL-S API models the service, profile, process and grounding ontologies of OWL-S in an easy to use manner. It is a widely used API in semantic applications. OWL-S API also presents interfaces for reasoning operations and utilizes Jena constructs at the back-end. At the bottom of the hierarchy we have Pellet reasoner for OWL reasoning operations.

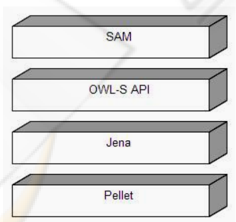

Figure 2: Software components of matchmaking agent.

We believe that a discrete scale (exact, plug-in, subsume, and fail) of service classification is not sufficient for a matchmaking process. On the other hand, semantic ranking of services can capture a set of services that are lost in a discrete scale match. Semantic similarity assessment is a crucial step for the ranking process. In our proposed system, we present value-added similarity assessment approaches between service and request parameter pairs.

4.1 Matching Algorithm

Previous research has shown that bi-partite graph matching algorithm is a good fit for finding matching parameters in a service and request pair (Herbert Alexander Baier Saip, Claudio Leonardo Lucchesi, 1993). Bi-partite graph matching provides us a solution for parameter pairing problem. We consider the inputs and outputs as separate cases and partition the service parameters and request parameters to form the bi-partite graph. The similarity assessment process of our matchmaker assigns weights for each parameter pair on this bi-partite graph. A maximum weight match on the final graph leaves us with the optimum matching parameter pairs and with a score that is sum of the weights between matched parameter pairs. We repeat this process for each service and request pair and finally rank the services according to their score from bi-partite graph matching algorithm.

As we stated before the process that differentiates the services is the similarity assessment process. We consider OWL-S profiles of service definitions and assign similarity scores for input and output parameter pairs. We present the following value-added features for similarity assessment: Subsumption based similarity, WordNet based similarity, similarity distance information and WordNet similarity assessment.

4.1.1 Subsumption based Similarity Assessment

We make use of OWL-DL constructs *subClassOf, disjointWith, complementOf, unionOf and intersectionOf* to assess concept similarity based on subsumption. If two concepts are explicitly stated to be complement or disjoint, a zero score is directly assigned. Otherwise, we check for subclass relation and also assess according to property level assessment procedure described below.

We wanted to capture similarity values in bi-partite graph since it is important to decompose concepts that include the characteristic of "a union of". Following this approach, we always pair and assess score for atomic concepts in matchmaking process.

4.1.2 Property-level Similarity Assessment

We have assumed that in matchmaking it is also important to have properties and their associated range in measuring the degree of match. Such as, if two concepts have similar properties (properties having subclass relation) and their range classes are similar, then this improves their level of similarity.
Using property level similarity assessment ranks a service that would normally be eliminated by a conventional matchmaker. For example, a user request may favour a particular author for a novel. A service, which returns articles that are written by that particular author, will have a high score even though the concept of “an article” does not compare to the concept of “a novel”. Therefore our proposed system returns positive results for concepts that have similar properties as well as the similar concepts.

4.1.3 Similarity Distance based Assessment

To represent similarity distance information we applied N-ary relation pattern in OWL, which is used to represent additional attributes on a property. The additional attribute in our case is the similarity distance value. Figure 3 shows how this pattern is organized:

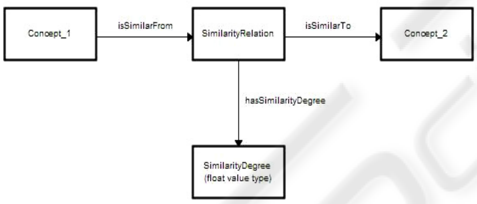

Figure 3: N-ary relation pattern in OWL, representing similarity distance information.

SimilarityRelation concept is introduced as a class with this pattern and the similarity distance value is represented as the range of *hasSimilarityDegree* property of this concept. The similar classes are represented as Concept_1 and Concept_2 in Figure 3.

We follow the standards approach by representing similarity distance information in OWL, which can be imported and used in other ontologies (Şenvar, M. and Bener, A., 2006). Similarity distance information is useful in reflecting user’s profile on the ontology. The importance and relatedness of concepts for the user are represented as weights on the ontology. In addition, if similarity distance annotation is not found between two concepts, then a default distance value is assigned according to the following formula:

$$Sd_{x,y} = 1/|subClassOf(x)_{direct}| \quad (1)$$

In the above formula $Sd_{x,y}$ represents similarity distance between concepts x and y and $|subClassOf(x)_{direct}|$ represents the number of elements in set of direct subclasses of concept x.

4.1.4 WordNet based Similarity Assessment

WordNet organizes words into synonym sets, which are also linked to each other representing a semantic relation. In our matchmaker we take WordNet as a secondary source of information with the ontology repository. We aimed at reasoning with these highly structured information sources in order to get more reliable result sets.

We make use of *wordnet::similarity* open source project to assess similarity score among words. The path length criterion is used for score assignment. The parameter types of services are presented as input to wordnet::similarity module.

5 EVALUATION AND RESULTS

In order to evaluate the performance of our proposed matchmaking agent we extended the book ontology in OWL-S Service Retrieval Test Collection (OWL-S TC) and also modified related request and service definitions accordingly (Mahboob Alam Khalid, Benedikt Fries, Patrick Kapahnke,, 2006). As shown in Figure 4, we added subclasses of *Magazine*, namely *Foreign-Magazine* and *Local-Magazine* classes.

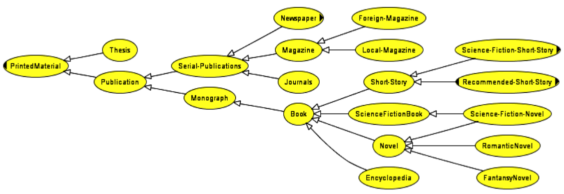

Figure 4: Printed Material ontology section.

As shown in Figure 5, we created subclasses of *Publisher: Ordinary-Publisher, Alternative-Publisher and Premium-Publisher.* We also created *Local-Author and Foreign-Author* classes, which are subclasses of class *Author.*

The matchmaking agent is developed in Java and it makes use of open source semantic web libraries like OWL-S API and Jena. We also used Pellet as the reasoning engine for OWL operations.

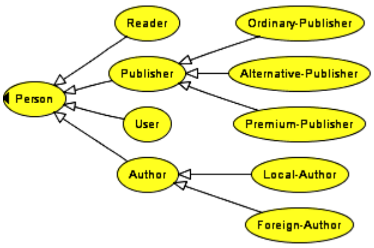

Figure 5: Person ontology section.

To represent subsumption reasoning, similarity distance based assessment and property-level similarity assessment capabilities we define the following request and services as described in Table 1:

Table 1: Test request and service set.

	Inputs	Outputs
Request	Ordinary-Publisher, Novel, Paper-Back	Local-Author, Genre
Service 1	Publisher, ScienceFictionBook	Author, Price
Service 2	Book, Alternative-Publisher, Book-Type	Publisher, Price, Date
Service 3	FantasyNovel, Author	Price, Comic
Service 4	Newspaper, Book-Type, Person	Review, Fantasy
Service 5	Publication, Book-Type, Reader	Time, Publisher

For the above test collection the property level similarity assessment plays an important role. Even though *Novel* concept has no subclass relation with *ScienceFictionBook* concept, both concepts have properties like *writtenBy* and *publishedBy*. Thus, our matchmaker applies a subsumption reasoning on ranges for these properties, which are Author with its subclasses, and *Publisher* with its subclasses. Finally, an additional score is provided for these services. A conventional matchmaker would have ignored these services as a "fail".

The property level matching score is determined by the following formula:

$$Sp_{x,y} = w_p * Subsumption_{x,y} \tag{2}$$

In the above equation, $Sp_{x,y}$ represents property level match score between range concepts x and y.

We use the semantic score obtained through subsumption, property level matching and semantic distance. WordNet $_{x,y}$ represents the WordNet score for concept names. The coefficients for subsumption and WordNet are fixed at 0.9 and 0.1 after making several experimental runs. We plan to apply a neural network training approach to determine values for coefficients utilizing a large training data in future. The following equation represents how the subsumption score and WordNet score is considered as the final similarity score.

$$S_{x,y} = w_{sub} * Subsumption_{x,y} + w_{word} * WordNet_{x,y} \tag{3}$$

$S_{x,y}$, in the above equation, represents final similarity score between concepts x and y. $Subsumption_{x,y}$ represents semantic score obtained through subsumption, property level matching and semantic distance. WordNet $_{x,y}$ represents the WordNet score for concept names. The coefficients for subsumption and WordNet are fixed at 0.9 and 0.1 after making experimental runs. We plan to apply a neural network training approach to determine values for coefficients utilizing a large training data in future. To consider how semantic distance information affects our ranking we introduced the following weights into the book ontology as described in following list:

Publisher → Ordinary-Publisher: 0.2
Publisher → Alternative-Publisher: 0.5
Publisher → Premium-Publisher: 0.3
Author → Local-Author: 0.3
Author → Foreign-Author: 0.7
Magazine → Foreign-Magazine: 0.7
Magazine → Local-Magazine: 0.3
Book → Short-Story: 0.2
Book → Science-Fiction-Book: 0.4
Book → Novel: 0.3
Book → Encyclopedia: 0.1
Novel → Science-Fiction-Novel: 0.6
Novel → Fantasy-Novel: 0.2
Novel → Romantic-Novel: 0.2
Book-Type → Hard-Cover: 0.7
Book-Type → Paper-Back: 0.3

The ranking with semantic distance information is listed in Table 2 as follows:

Table 2: Service I/O similarity scores.

	Input Score	Output Score	Overall Score
Service1	0.916	0.143	0.452
Service 2	0.345	0.096	0.195
Service 3	0.896	0.0003	0.444
Service 4	0.148	0.0003	0.059
Service 5	0.187	0.096	0.075

Considering the inputs Service 1 got the greatest score as it has a subsume relation with the request parameter Ordinary-Publisher and property-level matching with Novel parameter. The third request parameter is not considered, as the service only needs two. For the outputs we have Service 1 ranked higher than others. Indeed, none of the services satisfy all output requirements of the request. But considering similarity distance information the ranking is determined as above. Overall score favors the output score by assigning a higher weight to that, as the outputs of a service is more important to the requestor. As a result, Service 1 is the most related service for the specified request.

The similarity distance formulation is defined as follows:

$$Sd_{x,y} = Sd_{x,t} * Sd_{t,k} * \ldots * Sd_{m,y} \quad (4)$$

In the above equation, $Sd_{a,b} \in [0,1]$ for any a and b pair. $Sd_{x,y}$ represents similarity distance between concepts x and y. The product of similarity distance values on the path from x and y gives the value for $Sd_{x,y}$. If the concepts are not subclasses of eachother then we take the path including their first common parent in the hierarchy.

The final subsumption similarity score considering the similarity distance is shown below:

$$Ss_{x,y} = w_{direction} * Sd_{x,y} \quad (5)$$

$w_{direction}$ in the above equation, varies according to the subsumption property. Considering input parameters the service parameter to subsume the request parameter is favored and in the case of outputs the reverse is true. So, we set $w_{direction}$ coefficient to either 0.6 or 0.4 according to this approach. The values are determined after running experimental tests.

6 CONCLUSION

We proposed a novel advanced matchmaker, which introduces new value-added approaches like semantic distance based similarity assessment, property level assessment and WordNet similarity scoring. Instead of classifying candidate web services in a discrete scale, our matchmaking agent applies a scoring scheme to rank candidate web services according to their relevancy to the request.

The ranking property enables to include some of the relevant web services in the final result set whereas they would have been discarded in a discrete scale classification. Additionally, our proposed matchmaking agent improves subsumption-based matchmaking by utilizing OWL constructs efficiently and by considering down to a level of concept properties in the process.

We also introduced semantic distance annotation in ontology to represent relevancy of concepts to the user in a numerical way. Semantic distance annotations improve the relevancy of returned web service set as they actually represent user's view of ontology. WordNet similarity measurement is also presented as a value-added feature, which acts as a secondary source of information, strengthening the power of reasoning.

Our experiment results show that property level matching can be a good method to capture similarities between concepts that do not have a subsumption relationship. An improvement at this point can be to consider similarity between properties in addition to similarity of property range objects. Besides, similarity distance information provided us with a method to further differentiate the importance of concepts from the point of view of the user. The test results show how similarity distance plays an important role in service ranking.

We are still working on other ontologies to further test our matchmaker agent and plan to consider preconditions and effects of services in matchmaking process. This will require the use of SWRL (Semantic Web Rule Language) to represent preconditions and effects as rules in the system.

Another improvement will be to add context aware decision-making capabilities, enabling our matchmaking agent to reason based on user profiles, preferences, past actions etc. The system that we have presented can be considered as a basis for the development of context-aware agent.

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