Review of Machine Learning Approaches to Semantic Web Service Discovery

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***Abstract*---** **A Web service can discover and invoke any service anywhere on the Web, independently of the language, location, machine, or other implementation details. The goal of Semantic Web Services is the use of richer, more declarative descriptions of the elements of dynamic distributed computation including services, processes, message-based conversations, transactions, etc. In recent years text mining and machine learning have been efficiently used for automatic classification and labeling of documents. Various Web service discovery frameworks are applying machine learning techniques like clustering, classification, association rules, *etc.*, to discover the services semantically. This paper provides an exhaustive review of machine learning approaches used for Web Services discovery and frameworks developed based on these approaches. A thorough analysis of existing frameworks for semantic discovery of Web Services is provided in the paper.**

***Index Terms*---** **Machine Learning, Semantics, Web Services, Web services Discovery, Web Service Discovery Frameworks**

I. Introduction

Semantic Web Services (SWS) lie at the intersection of two important trends in the World Wide Web's evolution. The first is rapid development of Web service technologies and the second is the Semantic Web. Semantic Web focuses on the publication of more expressive metadata in a shared knowledge framework, enabling the deployment of software agents that can intelligently use Web resources. The driving force behind usage of Web services is the need of reliable, vendor-neutral, software interoperability across heterogeneous platforms and networks. Another important objective behind the development of Web Services has been the ability to coordinate business processes involving heterogeneous components (deployed as services) across ownership boundaries. These objectives have led to the development of widely recognized Web service standards such as WSDL, UDDI, and BPEL.

The Semantic Web brings knowledge-representation languages and ontologies into the fabric of the Internet; providing a foundation for powerful new approaches to organizing, describing, searching, and reasoning about information and activities on the Web (and also other networked environments). Semantic Web proposes to extend the traditional Web Services technologies on the way to consolidate ontologies and semantics such that services are able to dynamically adapt themselves to changes without human intervention.

The description of Semantic Web services enable fuller, more flexible automation of service provision and use and the construction of more powerful tools and methodologies for working with services. As a rich representation framework permits a more comprehensive specification of many aspects of services, SWS can provide a solid foundation for a broad range of activities throughout the Web service life cycle. For example, richer service descriptions can support:

- greater automation of service selection and invocation,
- automated translation of message content between heterogeneous interoperating services,
- automated or semi automated approaches to service composition, and
- more comprehensive approaches to service monitoring and recovery from failure [1].

Semantic Web Services enable the automatic discovery of distributed Web services based on comprehensive semantic representations. However, although SWS technology supports the automatic allocation of resources for a given well defined task, it does not entail the discovery of appropriate SWS representations for a given context. One of the major problems with existing structure are that UDDI does not capture the relationships between entities in its directory and therefore is not capable of making use of the semantic information to infer relationships during search.

Secondly, UDDI supports search based on the high-level information specified about businesses and services only. It does not get to the specifics of the capabilities of services during matching [2].

Several upper ontologies (i.e., application-independent) have been already proposed for service

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description. The first one was DAML-S [3] based on the DAML+OIL ontology definition language. However, with the wide acceptance of the Web Ontology Language (OWL) [4] family of languages, DAML-S was replaced by OWL-S [5]. On similar specifications various SWS frameworks like WSDL-S [6], WSMO [7], *etc.* were also developed. All these specifications, although sharing many modeling elements, differ in terms of expressiveness, complexity and tool support [8].

The only change desired in discovering the services semantically is that some metadata should be available which provide the functional description of Web services on which machine learning techniques like classification, clustering, association mining can be applied. Our contribution in this paper is to present a survey of SWS discovery frameworks based on machine learning approaches, methodologies and techniques applied for discovery of web services semantically and analyze the shortcomings of these approaches along with future direction to accomplish the job of Web Service discover successfully.

II. Machine learning based frameworks

In machine learning there are two major settings in which a function can be described: supervised learning and unsupervised learning. In supervised learning the variables under investigation can be split into two groups: explanatory variables and one (or more) dependent variables. The target of the analysis is to specify a relationship between the explanatory variables and the dependent variable as it is done in regression analysis. To apply directed data mining techniques the values of the dependent variable must be known for a sufficiently large part of the data set. In unsupervised learning all variables are treated in the same way, there is no distinction between explanatory and dependent variables. Supervised learning requires that the target variable is well defined and that a sufficient number of its values are given. For unsupervised learning typically either the target variable is unknown or has only been recorded for too small a number of cases.

Classification models are created by examining already classified data (cases) and inductively finding a predictive pattern. Classification problems aim to identify the characteristics that indicate the group to which each case belongs. This pattern can be used both to understand the existing data and to predict how new instances will behave. Clustering is a multivariate statistical technique that allows an automatic generation of groups in data. The result of the clustering is a partitioning of the collection of objects in groups of related objects. From a machine learning perspective clusters correspond to hidden patterns, the search for clusters is unsupervised learning, and the resulting system represents a data concept. Conceptual clustering is a machine learning paradigm for unsupervised classification distinguished from ordinary data clustering by generating a concept description for each generated class. Most conceptual clustering methods are capable of generating hierarchical category structures.

A. Classification Based Approaches to Semantic Web Service Discovery

Some of the Web service discovery frameworks combine text mining and machine learning techniques for classifying Web services and hence some semiautomatic and automatic methods have been proposed for Web service discovery through classification. Some approaches are based on argument definitions matching [9, 10], document classification techniques [11, 12] and semantic annotations matching [13]. MWSAF [9] is an approach for classifying Web services based on argument definitions matching. First, MWSAF translates the WSDL definitions into a graph. Then, MWSAF uses graph similarity techniques for comparing both. On similar lines Duo et al. [10] propose to translate a definition into an ontology, instead of a graph. Then, an ontology alignment technique attempts to map one ontology on another [7]. METEOR-S [11] describes a further improved version of MWSAF. The problem of determining a Web service category is abstracted to a document classification problem. The graph matching technique is replaced with a Na¨ıve Bayes classifier. To do this, METEOR-S extracts the names of all operations and arguments declared in WSDL documents of pre-categorized Web services.

Assam [14] is an ensemble machine learning approach for determining Web service category. Assam combines the Na¨ıve Bayes and SVM [15] machine learning algorithms to classify WSDL files in manually defined hierarchies. Assam takes into account Web service natural language documentation and descriptions. Automatic Web Service Classification (AWSC) compares a Web service description with other descriptions that have been manually classified. In AWSC, a two-stage process to classify a Web service is applied which uses text mining techniques at the first stage, namely preprocessing, to extract relevant information from a WSDL document and a supervised document classifier at the second stage, namely classification. This classifier deduces a sequence of candidate categories for a preprocessed Web service description.

B. Cluster Based Approaches to Semantic Web Service Discovery

The clustering methodology re-organizes a set of data into different groups based on some standards of similarity thus transforming a complex problem into a series of simpler ones, which can be handled more easily. Based on the clustered service groups, a set of matched services can be returned by comparing the similarity between the query and related group, rather than computing the similarity between query and each service in the dataset. If the service results returned are not compatible to the user's query, the second best cluster would be chosen and the computing proceeds to the next iteration

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Various clustering approaches have been used for discovering Web services. Dong [16] puts forward a clustering approach to search Web services where the search consisted of two main stages. A service user first types keywords into a service search engine, looking for the corresponding services. Then, based on the initial Web services returned, the approach extracts semantic concepts from the natural language descriptions provided in the Web services. In [17] Arbramowicz proposed an architecture for Web services filtering and clustering. The service filtering is based on the profiles representing users and application information, which are further described through Web Ontology Language for Services (OWL-S). In order to improve the effectiveness of the filtering process, a clustering analysis is applied to the filtering process by comparing services with related the clusters. Another similar approach followed in [18] concentrates on Web service discovery with OWL-S and clustering technology, which consists of three main steps. The OWL-S is first combined with WSDL to represent service semantics before a clustering algorithm is used to group the collections of heterogeneous services together. Finally, a user query is matched against the clusters, in order to return the suitable services.

Web services are clustered into the predefined hierarchical business categories in [19] and service discovery is based on a directory. In this situation, the performance of reasonable service discovery relies on both service providers and service requesters having prior knowledge on the service organization schemes. In [20] Probabilistic Latent Semantic Analysis (PLSA) is used to capture semantic concepts hidden behind words in the query and advertisements in services so that service matching is carried out at concept level. The Singular Vector Decomposition (SVD) of matrix approach of matching web services [21] has been extended with a different methodology called Probabilistic Latent Semantics Analysis (PLSA) based on aspect model. The model indirectly associates keywords to its corresponding documents by introducing an intermediate layer called hidden factor variable $Z = \{z_1, z_2, ..., z_k\}$[22].

Clustering Probabilistic Semantic Approach (CPLSA) discussed in [24] is an extension of [20], uses a dynamic algorithm that partitions a service working dataset into smaller pieces. It includes the two main phases: eliminating irrelevant services and matching services at semantic concept level. Once the irrelevant services are eliminated, a Probabilistic Latent Semantic Analysis approach is applied to the working dataset for capturing semantic concepts. As a result, Web services are clustered into a finite number of semantically related groups. The Semantic We Service Classification (SWSC) method discussed in [25] analyses the WSDL and checks its configuration and structure for further processing. The WSDL information of Web services is transformed in a richer semantic representation language OWL-S [4] using a series of methods.

The hierarchical agglomerative clustering method, which is often used in information retrieval for grouping similar documents, is used in [27] for Web service clustering. This method uses a bottom-up strategy that starts by placing each Web service in its own cluster, and then successively merges clusters together until a stopping criterion is satisfied. The clusters (terms representing Web services) are stored in the UDDI registry database. The SWSC method improves the search function by retrieving the best offers of services using the cluster matching. The SWSC method ranks the matched Web services and indicates the degree of relevance according to the term existence in clusters.

C. Context-Aware SWS Discovery

Contexts have increasingly been considered for better service provision. Dey [27] describes a context-aware computing system as a system that uses contexts to provide relevant information and/or services to the users, where relevancy depends on the user tasks, while Korkea-aho [26] defines contexts as any situational information that is available at the time of interaction between users and computing systems. Contexts can be useful for service discovery also. The UDDI can better perform if contexts of service consumers, service providers, and Web services are considered at discovery time. Context awareness has been applied in Web services discovery researches. The WASP project [27] attempts to enhance the standard UDDI into UDDI+ by adding the semantic and contextual features. Their approach focuses on semantic analysis of service provider contexts which are described by the ontology-based DAML-S specification, and hence their contexts are static only.

Doulkeridis *et al* [29] propose a context-aware service discovery architecture which accommodates various registry technologies including the UDDI and ebXML registry, but they consider the provision and consumption of services via mobile devices. Their approach therefore focuses on contexts related to mobility and handheld devices and does not cater for a generic context model.

Lee *et al* [30] enhances context-aware discovery by introducing context attributes as part of service descriptions in the service registry but their contexts are dynamic attributes only. The CB-SeC framework [31] also enables more sophisticated discovery and composition of services, by having a WSDL of a Web service augmented with context functions; these context functions will be invoked to determine the values of the service contexts. In this way, however, the WSDL will be cluttered with operations that do not reflect service capability. Keidl *et al* [32] introduces the concept of context type in their context framework but they focus on adapting service provision according to the consumer's contexts which are specified under particular context types; their framework does not consider service discovery.

Conceptual Spaces (CS), introduced by Gärdenfors [32,33], follows a theory of describing entities at the conceptual level in terms of their natural characteristics similar to natural human cognition in order to avoid the symbol grounding issue. Semantic similarity between situations is calculated in terms of their Euclidean

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distance within a CSS. Context-aware discovery and invocation of Web services and data sources is highly desired across a wide variety of application domains and subject to intensive research throughout the last decade [34, 35, 24] .

Authors in [37] propose that extending merely symbolic SWS descriptions with context information on a conceptual level through CSS enables similarity-based matchmaking between real-world situation characteristics and predefined resource representations as part of SWS descriptions. CSS are mapped to standardized SWS representations to enable the context-aware discovery of appropriate SWS descriptions and the automatic discovery and invocation of appropriate resources - Web services and data - to achieve a given task within a particular situation.

D. Web Services Discovery Based On Schema Matching

In [31] the authors propose a SVD-Based algorithm to locate matched services for a given service. There algorithm uses characteristics of singular value decomposition to find relationships among services. But it only considers textual descriptions and can not reveal the semantic relationship between web services. Wang et el [38] proposed a method based on information retrieval and structure matching. Given a potentially partial specification of the desired service, all textual elements of the specification are extracted and are compared against the textual elements of the available services, to identify the most similar service description files and to order them according to their similarity. Approach in [38] is similar to that followed in [16] but here focus in is on the semantic similarity not the structural similarity. Woogle [16] develops a clustering algorithm to group names of parameters of web-service operations into semantically meaningful concepts. Then these concepts are used to measure similarity of web-service operations. It relies too much on names of parameters and does not deal with composition problem.

A schema tree matching algorithm has been proposed in [23], which employs a cost model to compute tree edit distances for supporting web-service operations matching and catches the semantic information of schemas and then the agglomeration algorithm is employed to cluster similar web- service operations and then rank them to satisfy a user's top-k requirements.

E. Some Prevalent Frameworks and Methodologies

A considerable body of research has emerged proposing different methods of improving accuracy of Web service discovery. A Web service discovery method combining semantic and statistical association with hyperclique pattern discovery [39] has been proposed. Algorithms using Singular Vector Decomposition (SVD) [15] and probabilistic latent semantic analysis [20] have been proposed to find the similarity between various Web services to enhance the accuracy of service discovery. However none of these methods provides empirical and theoretical analysis showing that these methods improve the process of Web service discovery. In [36] authors proposed an extension of SVD [15] to support-based latent semantic kernel to further increase the accuracy of Web service discovery by using random projection [20] for service discovery. In random projection, the initial corpus is projected to l dimensions, for some $l > k$, where k is the dimension of the semantic kernel, to obtain a smaller representation which is close to the original corpus and then perform SVD on the reduced dimension matrix where the semantic kernel has been created on a large Wikipedia corpus for dimensionality reduction by introducing the concept of merging documents as well as using the constructed kernel on a general-purpose corpus to find semantically similar Web services for a user query.

Hyperclique pattern [39] are described as a type of association pattern containing items that are strongly associated with each other. Every pair of items within a hyperclique pattern is guaranteed to have the uncentered correlation coefficient above a certain level. When used in Web services field, items are the input or output parameters and a transaction is the set of input and output parameters for individual web service. Hyperclique pattern discovery can be adapted to capture frequently occurring local operation parameters' structures in web services, where parameters of a web service are represent as a vector, and each entry records the terms of the operations' input and output, thus each of these collections of terms forms a transaction. The web service collection is mined to find the frequent hyper clique patterns that satisfy a given support level and h-confidence level [23]. This is followed by a pruning of the hyper clique patterns on the basis of the ranking of semantic relationships among the terms.

III. COMPARITIVE ANALYSIS OF EXISTING FRAMWORKS

The major concerns in Semantic Web Service Discovery are that all new services do not have semantic tagged descriptions and vast majority of already existing web services do not have associated semantics. The problem of discovering Web services semantically is that there are too few annotated services and hence, semantic approach suffers from a cold-start problem as it assumes that a corpus of previously annotated services is available. Incorporating semantic annotating support to Web service is necessary.

A sensible classification system may "guide" the annotating process by deducing a handful set of similar services. Efforts for classifying Web services have several shortcomings. Natural language documentation, usually present in WSDL files and service registries have not been considered thoroughly.

Some of frameworks are based on the false premise that an operation and its argument names are independent, while some do not consider natural language documentation. Some frameworks assume that a corpus of previously classified services is available which generates the inability for dynamically creating categories without re-building the classifier.

Clustering annotated resources enables the definition of new emerging concepts (concept formation) on the grounds of the concepts defined in a knowledge base;

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supervised methods can exploit these clusters to induce new concept definitions or to refining existing ones (ontology evolution); intentionally defined groupings may speed-up the task of search and discovery.

Although the idea of clustering of similar Web services into a group is well supported and appreciated but it lacks a common base. Some authors propose hierarchical clustering while others prefer agglomerative clustering. The major effort required it is to have incremental clustering and dynamic classification.

A common problem with the SVD based approaches is that the computation of the high dimensional matrix representing the training documents is expensive. There have been some attempts to reduce the dimensionality of matrix prior to applying SVD.

Current SWS frameworks such as WSMO and OWL-S address the allocation of distributed services for a given (semantically) well-described task but none of the Web services fully solve the issues related to symbolic Semantic Web -based knowledge representations. Although lot of research has been done in this area and the entire research is moving in right direction but still no major breakthrough has been achieved and a lot more needs to be done to accomplish the task of Semantic Web service discovery.

Meta data based classification is a realistic option as they produce more specific semantic types. Combining metadata and content-based classification can indeed improve the performance of semantic based discovery. If we try to explore the clustering option then incremental clustering approach might be more suitable.

Functional description of Web service can be provided in documentation tag of the published service as this will serve as an additional sources of information and it semantically annotates the services, which can be easily extracted by text pre-processing techniques including detagging, tokenizing, stop word removal, etc.

Using trained classifiers is not accurate enough and soft classification based frameworks should be considered. For more effective ranking of the results, semantic weights should be associated to the retrieved set of web services.

Applying content based classification algorithm is an efficient method which can be used to classify web services into their respective groups. Pattern learning algorithms are another option which can be used to identify similar patterns in heterogeneous data and match them semantically.

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- List of potential reviewers
- Potential authors to the issue
- Tentative time-table for the call for papers and reviews

If a proposal is accepted, the guest editor will be responsible for:

- Preparing the "Call for Papers" to be included on the Journal's Web site.
- Distribution of the Call for Papers broadly to various mailing lists and sites.
- Getting submissions, arranging review process, making decisions, and carrying out all correspondence with the authors. Authors should be informed the Instructions for Authors.
- Providing us the completed and approved final versions of the papers formatted in the Journal's style, together with all authors' contact information.
- Writing a one- or two-page introductory editorial to be published in the Special Issue.

Special Issue for a Conference/Workshop

A special issue for a Conference/Workshop is usually released in association with the committee members of the Conference/Workshop like general chairs and/or program chairs who are appointed as the Guest Editors of the Special Issue. Special Issue for a Conference/Workshop is typically made of 10 to 15 papers, with each paper 8 to 12 pages of length.

Guest Editors are involved in the following steps in guest-editing a Special Issue based on a Conference/Workshop:

- Selecting a Title for the Special Issue, e.g. "Special Issue: Selected Best Papers of XYZ Conference".
- Sending us a formal "Letter of Intent" for the Special Issue.
- Creating a "Call for Papers" for the Special Issue, posting it on the conference web site, and publicizing it to the conference attendees. Information about the Journal and Academy Publisher can be included in the Call for Papers.
- Establishing criteria for paper selection/rejections. The papers can be nominated based on multiple criteria, e.g. rank in review process plus the evaluation from the Session Chairs and the feedback from the Conference attendees.
- Selecting and inviting submissions, arranging review process, making decisions, and carrying out all correspondence with the authors. Authors should be informed the Author Instructions. Usually, the Proceedings manuscripts should be expanded and enhanced.
- Providing us the completed and approved final versions of the papers formatted in the Journal's style, together with all authors' contact information.
- Writing a one- or two-page introductory editorial to be published in the Special Issue.

More information is available on the web site at http://www.academypublisher.com/jait/.