Ontologies: A Review of Web Service Discovery Techniques

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Abstract

Web service discovery has been a challenging activity since a long time and is still a problem area to find the right service as per user's criteria. Web service discovery process entails finding the most relevant service according to the user's requirements. With the proliferation of web services, demand for automatic web service discovery framework has increased to provide services highly relevant to user requirements. Discovery of web services is an important step from user's perspective, since it is the first activity in service consumption. If web services cannot be discovered, they will become useless. Though this area has been the attention of research community since long, still the web services discovery remains a challenge for organizations using SOA (service oriented architecture). In this paper, we focus on various discovery processes of the web services and its related challenges. Human intervention is often needed to interpret the meaning in order to select and invoke web services. This leads to error-prone and time consuming processes. So, the process of service selection is not fully automated and requires researcher's attention to address the problem. There exist various approaches to address this problem with majority of the approaches using syntax based techniques. With the maturity of semantic technology, current trend is towards applying semantic based approaches. These approaches uses variant of techniques and ontology is one of the prominent techniques. There have been many literature surveys covering both semantic and syntactic based approaches. It has been observed that there is lack of study on ontology based approaches for the web services discovery. This paper provides an extensive survey on purely ontology based techniques, highlighting the state-of-the-art approaches. The objective of this survey is to help new researchers, who are interested to study and contribute into this research domain.

Keywords: ontology; web service; semantics; classification; quality of services; semantic matchmaking

1. Introduction

Web service is a standardized way of integrating web based applications using XML, SOAP, web service description language (WSDL) and Universal Description, Discovery and Integration (UDDI) open standards over an Internet protocol backbone. Web services allow different applications from different sources to communicate with each other without custom coding. WSDL is used for describing the services available and UDDI is used for listing what services are available. Since, all communication is in XML, web services do not depend on any operating system or programming language and hence it is both language and platform independent. However, the WSDL do not provide sufficient semantic support that can be processed by machine leaning algorithms. UDDI acts as a repository for publishing, searching and retrieving web services provided by a service provider. A service provider develops services with certain functional capabilities and publishes them in central registry. The registry stores the advertisements of the functional capabilities of the web. Figure 1 shows the model of web service discovery system, where a service provider publishes the services in a service registry. A service consumer searches

the service in the registry. A matching mechanism is required that evaluates the advertised web services with the consumer queries for the discovery of the web services.

The worldwide acceptance of web services is enabled by XML-based standards such as WSDL [1], UDDI [2], and SOAP [3]. But, the XML based specifications support only the syntactical descriptions of the functionality supported by the services. So, this still requires human interventions for the web service discovery. The evaluation of semantic web has motivated researchers to enrich the web services with the sematic information, which is interpretable by machines. This automates the core activities of web services like- discovery, composition, selection and invocation. The main objective of semantic web service technology is to automate web service discovery and minimize the manual discovery process by enabling applications and agents to automatically identify, integrate, and execute the resources to achieve the user objectives. To support the automatic web service discovery, different semantic languages have evolved. These languages describe the functionality of services in a machine interpretable form. Ontology based approaches are seen as an effective way to address the web service discovery problem as discussed in following sections. This paper provides comprehensive review of the various attempts by various researchers using ontology based approaches in the area of web service discovery.
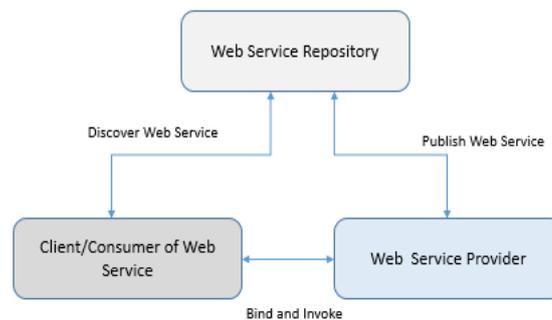
Figure 1. Web Service Model

Our contribution in this paper is to present a survey of ontology based approaches used in discovery of web services. This paper is organized in following sections: Section 2 provides a brief overview of the current challenges in web service discovery. Section 3 describes about the ontology based web service discovery process. Section 4 provides various studies on Web Service Discovery using Ontologies with comparative analysis and Section 5 concludes the paper.

2. Current Challenges in Web Service Discovery

Currently, there are three prominent methodologies prevailing for web services repositories like UDDIs, web portals like webservicex, xmethods, webservicelist *etc.*, and third by customized discovery of services explorations using a search engine. The complexity of web services vary from simple applications such as country information, weather report, credit checking etc. to complex business applications like banking, online ticket booking , insurance etc. It has been observed that current discovery mechanisms are limited in their search capabilities as they are mostly based on the keywords based matching. The web service consumer searches for a web service in UDDI registry and submits requirements using keywords. The keyword based techniques used in search engines are not efficient as many irrelevant services may be included in the description of the queried keywords. Also, the queried keywords may be semantically equivalent but syntactically different from the words in the offered services, leading to reduced recall. The key issue is that keywords are a poor way to capture the semantics of a service

request or service advertisement. Thus a different mechanism is needed, one that entails locating web services on the basis of the capabilities they provide. Semantics techniques in web service play an important role in seamless integration of diverse services which are based on different terminologies. For example, a service named "car" may not be returned from the query "automobile" submitted by a user, even they are obviously the same at the conceptual level.

Some of the other current challenges faced by web services are:

- Quantum of web services available on intranet, internet or private domains are quite high and it makes essential to have a very accurate process to find web services as per user need.

- Retrieval of services with similar functionality as required by a consumer is not much supported as UDDI supports keyword based matching, not context based matching.

- There is no support for manual annotation of web services descriptions.

- Lack of intimate knowledge about semantic languages and related toolkits for web services.

- Establishing web service discovery processes

- There are several existing approaches or tools to allow the web service discovery; however, these approaches often lack different attributes such as quality of service, reusability, incorporation of users' comments or annotations. All these prevent a user from selecting a web service for their efficient use.
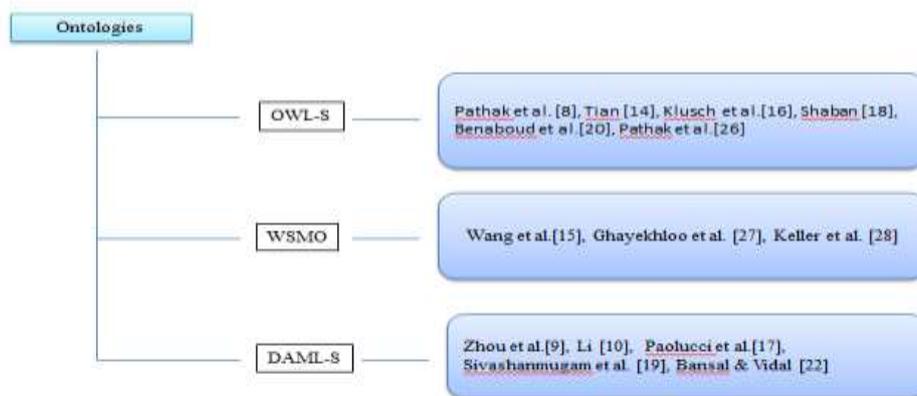
3. Ontology based Web Service Discovery

Ontology is a "formal specification of a shared conceptualization", provides a shared vocabulary, taxonomy of a particular domain which defines objects, classes, its attributes and their relationships. Ontology provides a structural framework for consolidating knowledge or information representation about a domain or part of a domain. This structure describes a set of concepts, properties and relationships among them. Today, "ontology" is exhaustively used in many areas such as software engineering, artificial Intelligence, information systems etc. Ontology adds semantics to web services and its properties and can significantly improve discovery methodologies. Researchers have proposed number of architectures, algorithms, standards and languages for the semantic web realization.

Ontologies have evolved to be a key technology to facilitate semantic web [15] and development of intelligent systems. Ontology can better contain and disambiguate the functionality, facilitate logic based matching of the requested and delivered service functions based on the inferred relationship. Evolution of ontologies is a promising approach to enrich web services description semantically. Several ontologies have been proposed for the service descriptions. Different semantics standards have been developed, like DAML-S [1], OWL-S [2], WSDL-S [3], and WSML [4]. DAML-S was the first based on the DAML-S ontology definition language. Later, DAML-S was replaced by OWL-S. These approaches take advantage of ontology to understand the WSDL files and users' request. In semantics based matchmaking, methodologies try to annotate WSDL files based on a specific ontology. The OWL-S (OWL for Services) is a standardized and popular ontology for web services and enables the automation of service discovery. This ontology language replaces the existing web services by adding semantics understandable by applications. OWL-S and web service modelling ontology (WSMO) facilitates the effort in creating the ontologies. They facilitate to describe the service descriptions and

makes easy the related advertisement and discovery process of web services. All these specifications differ in terms of complexity, expressiveness and kind of tool supported.

OWL-S provides capability-based web service search mechanisms. OWL-S structure contains three main parts known as service profile, the process model and the grounding. The service profile describes what the service does and provides information such as name, description, owner and contact details of a service. The service grounding contains details about how it works how to interact with service, supported protocols, message formats, port number etc. WSDL-S was developed by IBM and is a proposed extension to the WSDL standard. WSDL-S extends standard WSDL to include semantic elements which should improve the reusability of web services by facilitating the composition of services, improving discovery, and enabling the integration of legacy software with a web services framework. WSMO is ontology based framework, which supports the interoperability and deployment of semantic web services. It provides a conceptual support and a formal language for semantically describing all relevant aspects of web services.

Figure 2. Ontology based Approaches

Table 1 show the comparative analysis of the prominent techniques *i.e.*, syntax based and ontologies based techniques used in web service discovery processes. It can be summarized that ontology based approaches are more suitable for the web service discovery processes, though they also have some associated challenges.

Table 1. Comparison of Web Service Discovery Methods

Approach	Merits	De-merits
Syntax based approaches	• Simple and mostly used technique. • keyword-based search is more familiar to the user • Standards already established -UDDI	• Mostly requires human interaction • Unable to select similar service • low precision of selection • Not suited for automatic processing
Ontology-based Approaches	• Reduces the manual discovery process and allows automatically dynamic discovery of web services. • Reliable and effective Methodology	• End users should be familiar with the semantics of web service and its descriptions, implementation details, which makes usage cumbersome for them. • The discovery space is often

	• Effectiveness and relevancy of discovered web services can be enhanced by extending semantics through standards like OWL, WSDL-S, WSSMO etc.	limited to some web services that follows a particular description standard. • Require ontology mapping to support interoperability between ontologies and is a more complex technique.

3.1. General Framework for Web Service Discovery using Ontology

Figure 3 shows the general framework for the ontologies based web service discovery. It has main part as user query handling, match making, ontology based descriptions of web services. A web service provider publishes their services to a registry (UDDI) and stores the service descriptions through a user interface. Service advertisements are semantically annotated using ontology language OWL-S and loaded into the repository. Service providers   provide domain ontologies for the service functionality, which are parsed and kept in an ontology repository.
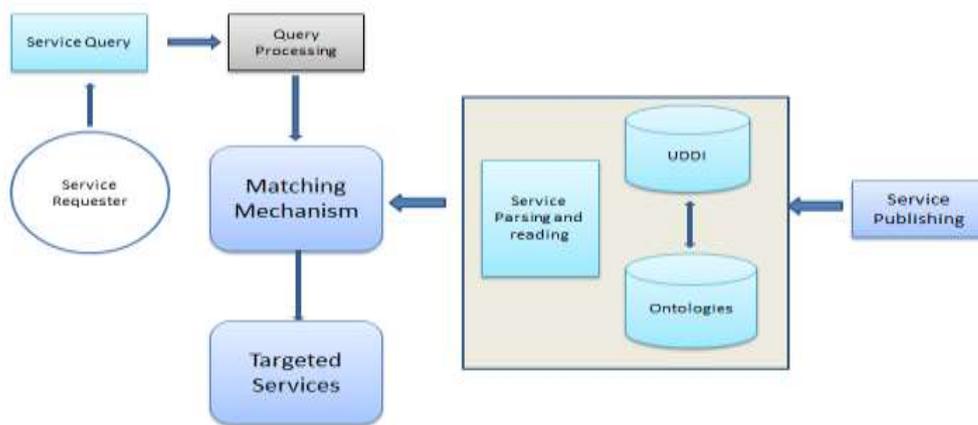
Figure 3. A Standard Web Service Discovery Process using Ontologies

A service consumer is provided with an interface to enter a service request. The semantic similarity between the consumer request and the service descriptions are computed using various matching mechanisms. A matching engine matches the keywords in the user query and returns the results in the form of service list to consumer. Majority of the current approaches vary in terms of ontology technique used and match making algorithms.

4. Web Service Discovery using Ontologies

Many of the discovery strategies uses the QoS based approaches to refine the search. Pathak *et al.*, [8] presented a framework using ontology-based flexible discovery of semantic web services. They demonstrated how a user's query can be transformed into queries which can be processed by a matchmaking engine. They also incorporated user specified preferences in terms of QoS to generate ordered list of web services. In future they planned to extend the approach to support service invocation and workflow composition for specific data-driven applications in a computational biology.

Zhou *et al.*, [9] proposed a framework using DAML-QoS ontology for specifying Quality of service attributes and metrics. They investigated on the semantic QoS speciation and introduced a design principles Based on the specification conformance,

they introduced the QoS matchmaking algorithm with multiple matching degrees. However, their framework assumes a single QoS ontology for the web service advertisers and consumers, and does not consider specification of semantic correspondences. Also, there is no provision to specify ranking criteria based on non-functional attributes for the service selection.

Lei and Horrocks [10] explored semantic and web services technologies to enable support of service discovery and advertisement in e-commerce. They presented the design and implementation of a service matchmaking prototype which makes use of DAML-S based ontology. They also proposed a Description Logic reasoner to compare ontology based service descriptions. They presented the results in to a realistic agent based e-commerce use case.

Maximilien and Singh [11] proposed ontology and an agent based framework called Web Services Agent Framework (WSAF) for the dynamic web services selection. The proposed agents collect, aggregate and share various services QoS data. Web service based software applications are configured dynamically by the agents. They proposed a QoS ontology for representing the generic quality of web services. Their future area of research would be to prevent malfeasant agents from biasing the agencies' data.

Adala et al., [12] proposed a framework that allows semantic web service discovery based on natural language keywords. They employed Language Processing (NLP) to match user query, which is expressed in natural English language with the semantic web service description. They also presented an efficient matching procedure to figure out the semantic distance between ontological concepts.

Paliwal et al., [13] presented an integrated approach for automated service discovery. Their approach is based on semantic-based service categorization and semantic based service selection. For service categorization, they proposed an ontology based categorization of web services into the functional categories. This lead to better service discovery by matching the service request with an appropriate service description. For service selection, they used ontology linking and LSI. This extended the indexing procedure from syntactical to semantic level. Their experiments showed increased precision and recall and this lead to increase in the relevance of the selected web services. In the future, they proposed to extend the approach to allow service requests that are formed using specialized query languages.

Tian [14] proposed an OWL-S based approach for web service discovery with the improved performance (recall and precision) of web service search. Their approach uses service profile description for service matching and discovery. The main WSDL file properties used for matching include service name, inputs, outputs, service parameters and QoS related properties. They presented the integration architecture with semantic matchmaker based on OWL-S mechanism into the UDDDI framework. They further described web service publishing and discovery using the proposed semantic matchmaker. They also described the matchmaker algorithm.

Wang et al., [15] proposed an ontology language for QoS of web services in the WSMO context. They specified QoS ontology and its vocabulary using WSMO for annotating service descriptions. They also presented a QoS selection model and an associated selection mechanism using an optimum normalization algorithm.

Klusch et al., [16] proposed an approach for hybrid semantic web service matching methodology in OWL-S called OWLS-MX. This approach exploits both logic based reasoning and Information Retrieval (IR) methods. Their experimental evaluation concluded that building semantic web service matchmakers solely on description logic reasoners may be insufficient. For future work, they proposed development of more powerful approaches to service matching in the semantic web across disciplines.

DAML-S based language is used for the web service descriptions in [17]. They depicted how the capabilities of services can be shown in the profile section of the DAML-S description. They have shown results that how a user request and service

advertisement is carried out using a matching engine. They claimed that their matching algorithm provides a way for web service discovery, selection of services and their interoperations.

Shaban and Haarslev [18] addressed the problem of service matching requested by users by making use of OWL ontologies and the OWL reasoner RACER. They proposed framework called DECAF which integrates an agent for matchmaking, which employs OWL-S for matching the requirements with web service descriptions. They presented a new way to integrate ontologies with agents and reasoning the ontologies using RACER. They expect their prototype can be a good start point for switching to the emerging semantic web and using ontologies with mobile agents in a wider application area.

Sivashanmugam *et al.*, [19] proposed an approach based on the DAML+OIL ontologies to develop semantic web services, by annotating them with the shared ontologies. These annotations are used for discovery of relevant web services based on the annotations. They claimed that their approach may prove better to the current standards based industry approaches. Their approach involves using DAML-S for adding semantics to Web services description. They have discussed an algorithm for semantic discovery of web services which uses functionality of the service as the main criterion for search.

In this paper, they propose an ontology-based OWL-S extension to adding QoS to web service Descriptions [20]. They used an efficient semantic service matching which takes into account concepts properties to match concepts in Web service and service customer request descriptions. Their approach is based on an architecture composed of four layers: web service and request description layer, functional match layer, QoS computing layer and reputation computing layer. Future work included to compose the functionality of several web services into one composite and realize consumer preference and QoS-based web service composition.

Bansal and Vidal [21] proposed an approach based on DAML-S and the methodology presented exploits the additional information available in the service model. They extended the algorithms based on conventional approaches using comparisons of the requested and offered inputs and outputs of services.

Ji [22] proposed a method to build domain ontology based service search engine prototype. They presented a process to retrieve service components and observed many benefits like expand user query, refine user query, fuzzy query support. The method proposed by them provided benefits of improved recall and precision.

Zhang and Li [23] proposed a construction method and the formal description of Web Service Discovery Oriented Ontology. They have used a use case of travel domain, representing the descriptions of web services and support for the user query specifications with the domain support. They proposed an algorithm for web service discovery through way of manipulating the relations between ontology. Their future work would to work on the large scale web services data, compare the proposed system efficiency with other systems.

Sycara *et al.*, [24] defined a language called LARKS for agent advertisements and requests, and based on this language they proposed a Larks matchmaking process which performs both syntactic and semantic matching. They also used a concept language ITL in order to specify the concepts of ontologies. The used five different filters for the matching process: context matching, profile comparison, similarity matching, signature matching and constraint matching. However, the proposed model lacks in explaining how service requests will be specified by users. Also, the proposed approach considers the existence of a common vocabulary for all users.

Oundhakar *et al.*, [25] proposed an ontology based web service discovery mechanism (METEOR-S) to provide access to registries that are divided based on business domains and grouped into federations. They proposed a novel web service discovery algorithm, which supports the semantic heterogeneity with respect to multiple ontologies from the

same domain. They evaluated empirically and find their algorithm has better accuracy and is able to find correct matches even when services are annotated with different ontologies. They proposed mediator to enhance interaction between federations, dynamic/runtime association between registries, extend the service discovery algorithm to support fault matching for the future work.

It has been shown that how the non-functional requirements (QoS) can be incorporated into the service discovery approach so as to generate list of services including user functional requirements in [26]. They proposed an ontology-based flexible framework for semantic web services discovery. Their approach is based on user-supplied, context-specific mappings from user ontology to relevant domain ontologies to specify web services. They show how a user's query with certain selection criteria can be transformed into queries processed by a matchmaking engine. They plan to extend proposed approach to service discovery, service invocation and workflow composition for specific data-driven applications.

Table 2. Comparison of Ontology based Approaches

Approach	Ontology supported	Framework/ Approach Name	Scalable/ Flexible	QOS used	Specific Tool used/ Middleware / Agent used/ Reasoning	Ranking Used	Annotation support	Ontology Mapping used	request expansion	NLP Used
[8]	OWL-S	NS	Yes	Yes	JESS	Yes	No	Yes	No	No
[9]	DAML-S	NS	NS	Yes	RACER	No	No	No	No	No
[10]	DAML-S	NS	NS	No	RACER	No	No	No	No	No
[11]	QoS Ontology	WSAF	Yes	Yes	NS	Yes	No	No	No	No
[12]	OWL-S/WSMO	NS	Yes	No	Wordnet/SUMO	Yes	No	Yes	No	Yes
[13]	SUMO	NS	NS	No	Cosine similarity	Yes	No	Yes	Yes	Yes
[14]	OWL-S	UDDI	NS	Yes	NS	No	No	Yes	No	No
[15]	WSMO	NS	No	Yes	NS	NS	Yes	No	No	No
[16]	OWL-S	OWL-MX	NS	No	OWL-MX	NS	No	No	No	No
[17]	DAML-S	NS	NS	No	DAML+ OIL	NS	No	No	No	No
[18]	OWL-S	DECAF	Yes	No	RACER	No	No	No	No	No
[19]	DAML-S	NS	No	No	NS	No	Yes	Yes	No	No
[20]	OWL-S	NS	No	Yes	q-grams	Yes	Yes	No	No	No
[21]	DAML-S	No	NS	No	JESS	No	No	No	No	No
[22]	Domain Ontology	RDF	NS	No	NS	Yes	No	No	Yes	No
[23]	Web Service Oriented Ontology	WOKB	NS	No	NS	No	Yes	No	No	No
[24]	Domain Ontology	LARKS	NS	No	Middle Agents	Yes	No	No	No	No
[25]	Multi-Ontology	METEOR-S	Yes	No	NS	No	Yes	Yes	No	No
[26]	OWL-S	NS	NS	Yes	Jess & Jena	Yes	No	Yes	No	No
[27]	WSMO	NS	Yes	No	Logical Inference	Yes	No	No	No	No
[28]	WSMO	WSMO	Yes	No	NS	No	Yes	No	No	No

NS- Not Specified

A logical discovery framework based on semantic description of the capability of web services to improve the speed and accuracy of automated Web service discovery has been presented in [27]. Their framework improves discovery performance by adding two pre-filtering stages to the discovery engine and also tackles the scalability problem. In the first stage, they compared ontology of the user request and Web service categories. In second stage, they reduced number of comparisons as the web services are eliminated based upon a decomposition and analysis of concept. They evaluated the proposed approach using a new Web service repository, called WSMO-FL test collection. Logical inference is used for matching, which ensures that the user request is satisfied by the selected web service.

Keller *et al.*, [28] have shown that how WSMO can be used for service discovery. The WSMO has been used to provide a conceptual framework for semantic web services. They presented wide range of scenarios and approaches to achieve the automation of web services. Their main focus was semantic-based techniques for web service discovery.

From the study, it has been observed that semantic based approaches are simple and provides better accuracy. But there are some disadvantages as well like less flexibility and more processing time which affects the performance. Table 3 shows the comparison in between ontology and other techniques on the performance parameters.

Table 3. Comparison of Semantic based and Syntactic based Approaches

Features	Semantic Approach	Syntactic / Other Approach
Accuracy	High	Low
Complexity	High	Less
Flexibility	High	low
Processing time	More	Less
Reliability	High	Less

Challenges of ontologies in web service discovery:

- There has been less research work in the field of semantic web service that targets to qualitatively enhance or upgrade web service ontologies or which can facilitate use of ontologies and improve the selection process

- It is a cumbersome task to develop a common ontology for countless web services

- It has been observed that there is almost no information regarding the challenges the researchers or projects faced while using the ontologies

- It is a cumbersome activity to allow all new web services to have semantic metadata annotations

- Furthermore, the majority of already existing services does not support the associated semantics and there are challenges on the potential conversion of existing non – semantic structure to the semantic descriptions

- It is a daunting task to annotate all web services, so the efforts for adopting semantically enriched web services has been limited to a few domains only, where research is more vigorous

- Semantic web services have not yet been fully adopted by the industry. One of the major challenges is the unavailability of semantically annotated content for use.

- Since existing web services follow mostly WSDL specifications, they should be upgraded to semantic web services. This can be achieved with the ability to automatically convert WSDLs into their semantic counterparts like SAWSDL or OWL-S.

4.1. Trends in Web Service Discovery Area

Currently, the discovery of web service is predominantly WSDL based, which involves lot of manual efforts for web service discovery. However, future efforts are for the automatic discovery of web services by enabling semantic integration in the web services descriptions. Current trends for the web services are for automatic discovery based on the capabilities, dynamic retrieval and invocation methods. Semantic technologies using ontologies are playing a significant role to facilitate these trends by enabling automatic retrieval of relevant information with better accuracy. This saves lots of manual efforts and knowledge overhead, thus saving time and increasing developer and user's

productivity. Currently, OWL-S based ontology language is the most standardized and perhaps is most comprehensive semantic web service technology deployed.

However, there are challenges while fully adopting the semantic web services by the industry:

- After viewing the literature, it is observed that more effort are required in following areas in order to make ontology successful and to meet future demands:

- Forming a close bonding between industrial efforts like XML, RDF, WSDL, WSFL and research efforts like, DAML+OIL, OWL, DAML-S *etc*.

- Make exposure of the latest semantic technology to industry, addressing the industry needs for new technologies and facilitating them.

- Enhancing existing Web Service discovery framework that can support the metadata and advanced ontology-based service discovery.

- Building a core consortium for semantic related technologies and challenges and stabilise standardization of the processes.

- Exploring and extending semantic technology in web services.

5. Conclusion

Discovery system plays an important role in web service model for efficient web service retrieval. As web service discovery involves manual intervention, it is a cumbersome and time consuming task to find the web services as per a consumer needs. This necessitates the resolutions for automatic discovery techniques and takes attention of researchers. This paper presents a glimpse of the plethora of research work done globally in the area of web service discovery by employing the ontology techniques. Ontology has made significant progress and a number of ontology based web service discovery models, approaches, frameworks have been proposed to resolve this problem area. In this paper we described about the various challenges posed by existing web service discovery processes.

We have also highlighted some of the possible challenges of ontology based systems. We hope that this work will be helpful to advance the discussion of ontology and semantics based web service discovery technologies. We described about the various existing prominent techniques to address the problem of automatic discovery of web services and consume it.

We have surveyed various approaches for web service discovery with different strategies proposed and summarized their findings. It can be seen that combination of multiple techniques and different feature collection of web services are effective for further improvement. Some of the approaches take into account the concepts of semantics techniques, while some other focuses on extracted features of services. It is also seen that many approaches differ in the way matching of web services with the user queries are carried out. Some approaches also suggest clustering based techniques. It is observed that following areas can be further worked upon as highlighted below:

- Better matchmaking mechanisms

- Use of NLP techniques for better feature selections

- User query expansion techniques

- Improving and better use of existing ontologies standards

- Use of hybrid approaches for performance and accuracy improvement

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