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Semantic Web Service Discovery Approaches: A Comparative Study

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Abstract— Nowadays, Web services are well involved in business computing for the development of distributed applications through diverse networks. In fact, finding the appropriate Web service meeting users' requirements (Web service discovery) becomes a crucial issue. In the literature review, many Web service discovery approaches have been proposed to in order to make easy the Web service discovery process. Existing approaches are different in terms of objective, issue to handle with, used techniques/methods, etc. In this paper, we propose, first, a literature review on approaches addressing semantic Web service discovery. Second, we provide a comparative study between these approaches on the basic of multiple criteria such as scalability, heterogeneity, context-awareness, accuracy, etc.
Keywords— Semantic Web, Web Service Discovery, Comparison, Scalability, Accuracy, Context-Awareness, Heterogeneity

I. INTRODUCTION

Web Services are self-contained, modular, distributed and dynamic applications that can be described, published, located, or invoked over the network in order to create products, processes, and supply chains. These applications can be local, distributed, or Web based (IBM, 2015).

In this paper, we provide a comparative study on semantic Web service discovery approaches. This paper aims; (i) first, at exploring a set of recent semantic Web service discovery approaches: their contributions as well as challenges. (ii) Second, at providing a comparison between these approaches on the basic of multiple criteria.

The remainder of this paper is organized as follow:
Section 2 introduces the research questions as well as the followed research methodology.
Section 3 introduces the basic concepts concerning the main concepts of Web service discovery field.
Section 4 presents the retained Web semantic discovery-based approaches. Section 5 presents a comparative study between the already presented semantic Web discovery-based approaches.
Section 6 concludes the papers and underlines the main future work.

II. RESEARCH QUESTIONS AND METHODOLOGY

A. Research questions

The objective of this paper is to explore the opportunities offered by the relevant existing approaches for semantic Web service discovery as well as their limitations. Thereafter, we propose taxonomy of these approaches.

More precisely, we seek answers to the two following research questions:

- ***Research Question 1:*** *Which are the main challenging issues raised by semantic Web service discovery approaches?*
- ***Research Question 2:*** *Which are the solutions proposed regarding the raised issues and their limitations?*

B. Research methodology

In this research, we have analyzed eight recent approaches concerned by the semantic Web discovery paradigm. This set was selected after a large review of existing publications concerned by this field.

This research is performed by using different libraries which are mainly:

1) ACM Digital Library[1]
2) IEEE Xplore[2]
3) Springer Link[3]
4) Science Direct[4]

Throughout our research process, we run, essentially, three queries using the Google Scholar web search engine. The three search queries are the following:

Q1:"semantic web service discovery"+"approach"

Q2:"semantic web service discovery"+"platform"

Q3:"semantic web service discovery"+"model"

TABLE I presents the eight retained approaches, their publication year and their category (journal, conference, workshop, etc.).

TABLE I
TABLE I. CLASSIFICATION OF SEMANTIC WEB SERVICES APPROACHES BY: YEAR, CATEGORY AND SOURCE LIBRARY

	Approach	**Publication year**	**Category**	**Source library**
1	Xiaa et al.,	2019	Journal	Science Direct
2	Elgedawy et al.,	2017	Conference	ACM
3	Shen et al.	2019	Conference	Springer
4	Zhang et al.,	2018	Journal	Science Direct
5	Cheng et al.,	2017	Journal	IEEE
6	Wang et al.,	2017	Journal	IEEE
7	Chen et al.,	2017	Journal	Science Direct
8	Fethallah el al.	2015	Conference	ACM

Fig. 1 shows the distribution of the retained approaches according to their source library.

[1]https://dl.acm.org/
[2]http://ieeexplore.ieee.org/Xplore/home.jsp
[3]https://link.springer.com/
[4]https://www.sciencedirect.com/

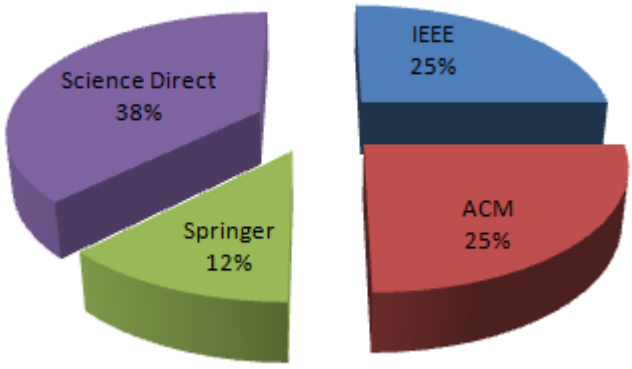

Fig.1 Distribution of retained approaches by source library.

III.BASIC CONCEPTS

A. Semantic Web

Semantic Web" refers to W3C's vision of the Web of linked data. Semantic Web technologies enable people to create data stores on the Web, build vocabularies, and write rules for handling data.

B. Web service

Web Services are self-contained, modular, distributed and dynamic applications that can be described, published, located, or invoked over the network in order to create products, processes, and supply chains. These applications can be local, distributed, or Web based (IBM, 2015).

C. Service discovery

Web service discovery is the process of locating existing web services based on the service requester‟s requirements, which match the services‟ functional and non-functional descriptions of the web service [5],

D. WSDL

Web Service Description Language is a standard for syntactic web service description, WSDL 2.0[24] used to describe the web service interface and the message exchange patterns (Structure of SOAP messages).

E. UDDI

Universal Description Discovery and Integration is a standard web service registry, that allows services providers through an API to publish his services, and services requesters to search for desired web services. UDDI offers a syntactic description of its content. However, it does not present semantic models to understand the user requests and web service capabilities.

F. Ontology

Ontology can be defined as a formal explicit specification of a shared conceptualization. A conceptualization is an abstract, simplified view of the world that we wish to represent for some purpose (Gruber, T.R., 1993; Studer, R., et al., 1998).

G. OWL-S

OWL-S (Ontology Web Language for Services)[7]: formerly DAML¬S, is an ontologies¬based web service description language, in OWL¬S each service is described using three XML¬Based parts which are: Service Profiles (to describe the web service

capabilities), Service Model (describing web service behaviors) and Service Grounding (to provide details about the web service invocation).

H. WSMO

WSMO (Web Service Modelling Ontology)[11]: provides a semantic modelling language for web services capabilities description. In WSMO, a web service is described using four core elements, which are: Ontologies, Goals, Web services and Mediators

I. SAWSDL

Semantic Annotations for WSDL and XML Schema (SAWSDL) defines how to add semantic annotations to various parts of a WSDL document such as input and output message structures, interfaces and operations. SAWSDL defines an annotation mechanism for specifying the data mapping of XML Schema types to and from an ontology; such mappings could be used during invocation, particularly when mediation is required.[3wc].

IV. SEMANTIC WEB SERVICE DISCOVERY APPROACHES

In this section we will present the eight retained semantic Web services discovery approaches.

A. Elgedawy approach

In this approach, the authors propose a new platform that can automatically change the discovery process phases and their realizing platform services based on the users' queries and contexts. In fact, it takes, first, the required discovery policy from users and finds the suitable discovery schemes, according to the context, thereafter. Finally, the framework arranges them as a collection of executable BPEL processes. DISCO platform has been validated throughout verification experiments in order to show highlight its adaptability and how it reconfigures itself to different discovery policies.

B. Shen et al., approach

In this paper, the authors propose a new measure of semantic similarity integrating multiple conceptual relationships (SIMCR) for Web service discovery. The proposed measure allows to ensure more accurate service-request comparison through the management of different conceptual relationships in ontologies.

The authors consider that each service or request is represented by vectors of terms (or words) that characterize the interface signature as well as the textual description. The authors validate the proposed approach and the experimental results confirm its effectiveness. Concerning the evaluation of the proposed approach regarding existing ones confirms that it outperforms the existing discovery methods, especially in terms of precision and recall.

C. Zhang et al., approach

In this paper, the authors propose an approach aiming at helping service requesters to obtain relevant services accurately with a keyword query by exploiting domain knowledge about service functionalities (service goals) extracted from textual descriptions of services. In fact, the authors propose to extract service goals from services' textual descriptions using an NLP-based method, on the one hand, and to cluster service goals by measuring their semantic similarities, on the other hand. The proposed approach is validated by integrating goal-based matching with two practical approaches: keyword-based and topic model-based.

D. Xiaa et al., approach

In this paper, the authors propose an efficient social like semantic-aware service discovery mechanism for large-scale IoT. According to the authors, the proposed mechanism can discover the desired services in a fast and scalable way. By considering the semantic similarity and the semantic relativity of two concepts in the domain ontology, the authors introduce the fuzzy logic method to calculate correlation degree for device ranking. Experimentations lead for a better performance comparing to the existing mechanisms.

E. Cheng et al., approach

In this paper, the authors propose a Web services discovery approach allowing extracting the underlying semantic structures of interaction interface parameters in order to help users find and employ Web services. In fact, the authors introduce a conceptual Web services description model that contains the type path for the interaction interface parameters in addition to the traditional text description. Throughout the proposed conceptual model, an extraction of the underlying semantics of the interaction interface is taken. This allows creating index libraries which can help to provide a high-efficiency. The experimental evaluation of this approach shows that it performs better than other Web service discovery methods in terms of both discovery time and precision/ recall rate.

F. WANG et al., approach

In this paper, the authors propose a Web service discovery approach based on common topic groups through some algorithms allowing mining common topic groups from the generated service topic distribution matrix. The proposed approach allows to minimize the number of candidate Web services during the process of Web service discovery and decreasing, therefore, the recall time. The approach is well validated and the obtained experiment results show its ability to maintain the performance of service discovery with decreasing the number of candidate Web services, ensuring, so, faster response time.

G. Fethallah el al. Approach

The authors deal with issues related to web service discovery and data fusion. They highlight certain limitations of current approaches, especially, regarding data fusion. They notice that a lot of existing aggregating models are not adequate for service matchmaking. Thus, they introduce a semantic hybrid matching approach that takes advantages of both logic approaches, based on formal reasoning, and non-logic approaches, based on information retrieval techniques and data mining. Concerning the experimentation, the authors run a set of experiments in order to investigate the performance of the proposed aggregation schema. In addition, according to them, the proposed approach is more effective than the individual matching algorithms.

V. COMPARATIVE STUDY

In this section, we provide comparison study between the approaches already presented in section 4. This comparison is based on multiple criteria which are respectively:

- *Basic concept/technique:* it identifies the main concept or technique on which the approach is based.
- *Issue:* identifies the main issue raised by the approach and for which, the authors propose the solution.
- *Proposed solution:* identifies the solution proposed by the authors in order to overcome the already identified issue.
- *Future challenges:* defines the main planed future work aiming at the improvement of the proposed solution.
- *Heterogeneity:* identifies if the Web service discovery process is able to deal with heterogeneities due to different platforms and data formats.
- *Scalability:* describes the ability of the proposed approach to grow and manage increased amount of data and resources.
- *Accuracy:* means the quality or state of being accurate or exact (precision).
- *Context-awareness:* identifies if the Web service discovery process takes into account by the proposed approach or not.
- *Validation/evaluation:* identifies if the approach is validated through experimentations and/or evaluated regarding existing work or not

The comparative table (TABLE II) highlights many standard concepts and techniques used by semantic Web service discovery approaches. Besides, many issues and suggested solutions are identified by the presented approaches. Concerning challenges, a set of future works is underlined by each retained approach.

TABLE II THE POSITIONING OF THE SEMANTIC WEB SERVICE DISCOVERY APPROACHES REGARDING THE PRESENTED CRITERIA.

Criteria / **Approach**	**Basic concept/ technique**	**Issue**	**Proposed solution**	**Future challenges**	**Scalability**	**Accuracy**	**Heterogeneity**	**Context-awareness**	**Validation/evaluation**
Elgedawy	BPEL	When diverse discovery tasks are required, service needs to be manually reconfigured, and different versions of the discovery service are created and managed.	Build a dynamic self-configuring discovery service.	Extending the framework by handling with more knowledge types	No	No	No	Yes	Yes

Shen et al.,	-Latent Dirichlet Allocatio(LDA) - Word2vec -Doc2vec -Skip-Thought	Difficulty to find target web services for users with efficient manner with existing clustering methods since they have used long text documents.	-Representation of the text descriptions of web services as vectors containing semantic information. -Extracting topic semantic information of web services according to its web service text description vector.	Reducing web service discovery time and discovering unsupervised sentence representations.	No	Yes	No	No	Yes
Cheng et al.,	-WSDL -WADL	-The difficulty to expect all new services to have semantic tagged descriptions. -Existing Web Services are specified using WSDL and do not have associated semantics. - The service requester may not be aware of all the terms related to the service request.	-Retrieving the underlying semantic concepts from service metadata. -Attempting to assist service consumers in finding similar service operations and potentially composable ones with high precision/recall rate and low time costing.	Finding an efficient method to evaluate the performances of the Web services themselves and apply those performance evaluations to improve the ranking of discovery results.	No	Yes	No	No	Yes

Criteria / **Approach**	**Basic concept/ technique**	**Issue**	**Proposed solution**	**Future challenges**	**Scalability**	**Accuracy**	**Heterogeneity**	**Context-awareness**	**Validation/ evaluation**
Wang et al.,	-Common Topic Group (CTGs) -SAWSDL-TC	How to quickly find the suitable Web services according to user queries.	Mining common topic groups from the generated service topic distribution matrix in order to minimize the number of candidate Web services during the process of Web service discovery.	-Leveraging more domain knowledge during the process of mining. -Modeling user preferences according to historical usage of services.	No	Yes	No	Yes	Yes
Fethallah el al.	Fuzzy logic	-Large number of services over the internet. -The ranking of services that fulfill a given request, is not always evident.	Establishing a relationship termed "fuzzy dominated function" which compares in a pair-wise manner, all the vector components of the matching instances.	-Adding other aggregating function. -Learn a weighting scheme for building the global ranking.	Yes	Yes	Yes	No	Yes
Chen et al.,	-Natural Language Processing Technique (NLPT) -Porter's stemming algorithm	Non-existing of semantic service discovery method that consider different conceptual relationships, including is-a (ISA), part-whole (has-a, or HASA), and antonomy (ANT), in combination with adjectives and adverbs in measuring the textual similarity.	-Developing two similarity measurement formulas, one for nouns/verbs and another for adjectives/adverbs. -Utilizing multiple conceptual relationships from WordNet.	- Apply disambiguation methods in order to improve the accuracy of similarity measure. - The design of scalable service discovery methods(e.g., cluster-based service searching).	No	Yes	No	Yes	Yes

Criteria / Approach	**Basic concept/ technique**	**Issue**	**Proposed solution**	**Future challenges**	**Scalability**	**Accuracy**	**Heterogeneity**	**Context-awareness**	**Validation/ evaluation**
Zhang et al.,	-Natural Language Processing Technique (NLPT) -Goal-oriented approach -Query expansion	Some concepts extracted from WordNet or domain ontologies may be irrelevant while some relevant ones are missing, which prevent obtaining desired services.	- Clustering the service goals extracted from textual service descriptions by measuring their semantic similarities. - Using a query expansion method to help service requesters refine initial queries by recommending similar service goals.	-Improving the goal-oriented query expansion approach by utilizing service goals selected by service requesters for queries. -Considering non-functional properties of services in addition to functional requirements. - Extracting semantic associations among service goals.	No	Yes	No	No	Yes
Xia et al.,	-Fuzzy logic method. -Social networks. - OWL	-Difficulty to achieve discovery process, due to the large e number of devices results in an enormous search space. -The network traffic become too large to be managed efficiently, giving raise to the scalability problems.	Developing a social-like semantic-aware service discovery mechanism for large-scale IoT	-Selecting a narrow set of friend relationships, each device can manage its 'friends' more effectively. - Address the mobility issue through edge computing. -Considering the security and privacy in the design process.	Yes	Yes	Yes	No	Yes

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Fig 2. shows the criteria already taken into account by the retained semantic Web service approaches.

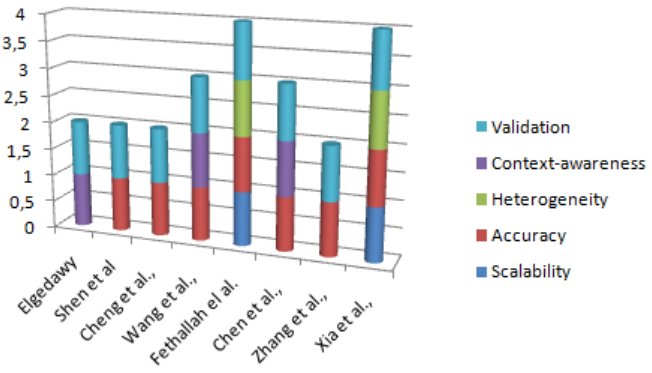

Fig 2. Distribution of the criteria according to the retained approaches

VI. CONCLUSIONS

The objective of this comparative study is mainly; (i) to review the most interesting semantic Web service discovery approaches: highlights their characteristics, the challenges they raise as well as the opportunities they offer, (ii) to summarize the essential methodologies and techniques used by these approaches and (iii) to highlight the limitations of each approach regarding other ones based on a set of relevant criteria.

Concerning scalability, it's taken into account only by the Fethallah et al., and Xia et al., approaches.

Concerning accuracy it is well considered in all retained approach except Elgedawy approach.

Heterogeneity is handled by Fethallah and Xia et al., approaches.

Context-awareness is considered by Wang et al., Chen et al., and Elgedawy approaches.

Finally, all the retained approaches confirm the performance and the efficiency of their approaches through experimentations.

Future work will propose an extended version of this study allowing studying new set of more recent semantic Web service discovery approaches and improving the comparative study throughout new criteria.

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