ENHANCED MATCHING ENGINE FOR IMPROVING THE PERFORMANCE OF SEMANTIC WEB SERVICE DISCOVERY

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To

Parisa Samimi, my loving wife

Nasrollah Mohebbi and Shayesteh Mazi, my beloved parents

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ABSTRACT

Web services are the means to realize the Service Oriented Architecture (SOA) paradigm. One of the key tasks of the Web services is discovery also known as matchmaking. This is the act of locating suitable Web services to fulfill a specific goal and adding semantic descriptions to the Web services is the key to enabling an automated, intelligent discovery process. Current Semantic Web service discovery approaches are primarily classified into logic-based, non-logic-based and hybrid categories. An important challenge yet to be addressed by the current approaches is the use of the available constructs in Web service descriptions to achieve a better performance in matchmaking. Performance is defined in terms of precision and recall as well-known metrics in the information retrieval field. Moreover, when matchmaking a large number of Web services, maintaining a reasonable execution time becomes a crucial challenge. In this research, to address these challenges, a matching engine is proposed. The engine comprises a new logic-based and non-logic-based matchmaker to improve the performance of Semantic Web service discovery. The proposed logic-based and non-logic-based matchmakers are also combined as a hybrid matchmaker for further improvement of performance. In addition, a pre-matching filter is used in the matching engine to enhance the execution time of matchmaking. The components of the matching engine were developed as prototypes and evaluated by benchmarking the results against data from the standard repository of Web services. The comparative evaluations in terms of performance and execution time highlighted the superiority of the proposed matching engine over the existing and prominent matchmakers. The proposed matching engine has been proven to enhance both the performance and execution time of the Semantic Web service discovery.

ABSTRAK

Perkhidmatan Web merupakan cara untuk merealisasikan paradigma Seni Bina Berorientasikan Perkhidmatan (SOA). Salah satu tugas utama perkhidmatan Web ialah penemuan yang juga dikenali sebagai penjodohan. Ini merupakan tindakan mencari perkhidmatan Web yang sesuai untuk memenuhi matlamat yang khusus dan menambah penerangan semantik kepada perkhidmatan Web sebagai kunci untuk membolehkan pengautomasian proses penemuan pintar. Penemuan pendekatan perkhidmatan Web semantik semasa, khasnya, diklasifikasikan kepada berasaskan-logik, bukan-berasaskan-logik dan hibrid. Satu cabaran utama yang masih harus ditangani oleh pendekatan semasa ialah penggunaan konstruksi sedia ada dalam penerangan perkhidmatan Web untuk mencapai prestasi yang lebih baik dalam penjodohan. Prestasi ditakrifkan dari segi ketepatan dan ingatan kembali sebagai metrik terkenal dalam bidang pencapaian maklumat. Selain itu, untuk mengekalkan masa perlaksanaan yang munasabah bagi penjodohan yang melibatkan banyak perkhidmatan Web merupakan satu cabaran yang penting. Dalam kajian ini untuk menangani cabaran ini enjin yang sepadan telah dicadangkan. Enjin ini terdiri daripada pencari jodoh berasaskan-logik baharu dan bukan-berasaskan-logik untuk mempertingkatkan prestasi penemuan perkhidmatan Web semantik. Pencari jodoh berasaskan-logik dan bukan-berasaskan-logik yang dicadangkan juga digabungkan sebagai pencari jodoh hibrid untuk penambahbaikan prestasi. Di samping itu, penyaring prapemadanan digunakan dalam enjin yang sepadan untuk mempertingkatkan masa pelaksanaan penjodohan. Prototaip komponen enjin yang sepadan dibangunkan dan dinilai dengan membandingkan keputusan dengan data daripada penyimpanan standard perkhidmatan Web. Hasil penilaian perbandingan dari segi prestasi dan masa pelaksanaan mempaparkan keunggulan pemadanan enjin yang dicadangkan berbanding dengan pencari jodoh sedia ada dan menonjol. Enjin yang sepadan yang dicadangkan telah terbukti dapat mempertingkatkan kedua-dua prestasi dan masa pelaksanaan penemuan perkhidmatan Web semantik.

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LIST OF ABBREVIATIONS

AP	-	Average Precision
API	-	Application Programming Interface
AUC	-	Area Under the Curve
B2B	-	Business-to-Business
B2C	-	Business-to-Customer
DL	-	Description Logic
DoM	-	Degree of Match
FOL	-	First-Order Logic
HTTP	-	Hyper Text Transfer Protocol
Iff	-	If and only if
IOPE	-	Inputs, Outputs, Preconditions, Effects
IR	-	Information Retrieval
LP	-	Logical Programming
MEP	-	Message Exchange Pattern
MOF	-	Meta-Object Facility
MWBG	-	Maximum Weight Bipartite Graph
NFP	-	Non-Functional Property

OWL-S	-	Ontology Web Language for Services
P2P	-	Peer-to-Peer
PoR	-	Probability of Relevance
QoS	-	Quality of Service
QRT	-	Query Response Time
R/P	-	Recall/Precision
RDF	-	Resource Description Framework
ROC	-	Receiver Operating Characteristics
SAWSDL	-	Semantic Annotations for WSDL
SME2	-	Semantic web service Matchmaker Evaluation Environment
SOA	-	Service Oriented Architecture
SOAP	-	Simple Object Access Protocol
UDDI	-	Universal Description Discovery & Integration
VoS	-	Value of Similarity
VSM	-	Vector Space Model
W3C	-	World Wide Web Consortium
WSDL	-	Web Service Description Language
WSDL-S	-	Web Service Description Language-Semantics
WSMF	-	Web Service Modeling Framework
WSML	-	Web service Modeling Language
WSMO	-	Web Service Modeling Ontology

WSMX	-	Web Service Modeling eXecution environment
XML	-	eXtensible Markup Language

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CHAPTER 1

INTRODUCTION

This chapter introduces the mainstream of this research work. Overview and background information of this research attempt are described. Later, research problems and objectives are detailed. Following that, scope and significant of the study are discussed. Finally, thesis organization is presented.

1.1 Overview

The Service Oriented Architecture (SOA) is a distributed computing paradigm that allows interaction between software components regardless of their platform, implementation, and location [1]. The building blocks of SOA are services which are pieces of functionality as software components exposed to be reused by other parties. Service providers offer these components by publishing them in some service registry or repository. Service consumers which may be either human users or software agents, request for a capability without any prior knowledge about existing services and their locations. Thus, for a consumer to use services, appropriate ones should be discovered.

One of the prominent technologies to realize the SOA paradigm is Web services. A Web service is a public interface of an application which can be invoked remotely to perform a business function or a set of functions. In addition, it is a self-contained, modular unit of application logic that provides business functionality to other applications over the Web using standard protocols. Web services have become the primary technology to enable distributed computing infrastructure for interoperability across different platforms [2]. Web services might undergo many processes during their life cycles such as discovery (locating different services suitable for a given task), selection (choosing the most appropriate services among the available ones), composition (combining services to achieve a goal), mediation (resolving heterogeneities in services interaction), execution (invoking services following programmatic conventions), and monitoring (controlling the execution process). In particular, Web service discovery which is often called matchmaking is the act of locating Web services that fully or partially fulfill a given objective. Service descriptions may be found by a requester during the development of a system as static, or during execution of a system as dynamic.

Semantic Web technologies aim to make data on the Web machine-processable. The key to enable this is through using ontologies as the sources of precisely defined concepts to annotate Web resources. Accordingly, Semantic Web services attempt to automate various usage tasks by enriching Web services with machine readable information. Semantic Web service discovery allows the construction of requests using concepts defined in a specific ontological domain [3]. During the process of matchmaking, the description of formalized goals of service requesters and semantic annotations of formalized Web services need to be compared in order to recognize common elements in these descriptions. By having both the advertised description and the requested query explicitly declare their semantics, the results of discovery are more accurate and relevant than conventional non-semantic Web service discovery.

Numerous approaches to Semantic Web service discovery have been proposed which are primarily categorized as Logic-based and Non-logic-based, and a more recent combination of Hybrid [4]. In general, Logic-based approaches use the explicit semantics that are described by the domain ontologies, whereas Non-logic-based approaches exploit implicit semantics of the services. Hybrid approaches combine both of these techniques to achieve more precise results.

1.2 Statement of the Problem

An overview of grand challenges in SOA and their implications are given in [5]. Some of these challenges are still remain open. They primarily include increasing the dynamics of SOA-related systems. In particular, dynamic reconfiguration of services (i.e., configuring the service infrastructure automatically at run-time) and service discovery should be enhanced to fully exploit the potential benefits of the SOA paradigm. Thus, discovery of services in a manner that increases the dynamics of SOAs is observed as an important challenge and the work at hand aims to address this challenge. Enhancing the process of service discovery requires making this process more accurate in an automated manner. Semantic description of services has been identified as a promising path towards this enhancement. However, the immediate problem for the discovery of Web services is not the lack of semantic descriptions, but there is a lack of approaches to take advantage of this description [5], [6].

One of the main challenges of Web service discovery is improving the performance by avoiding false results which can be either false positives (i.e., irrelevant Web services in the answer set) or false negatives (i.e., relevant Web services that are not included in the answer set). Current Semantic Web service discovery approaches of Logic-based, Non-logic-based and Hybrid categories employ different strategies to avoid the mentioned false results. However, there are still false results in the answer set of state-of-the-art approaches to Semantic Web service discovery [7], [8], [9]. False positive and false negative results are respectively used to calculate the precision and recall measures of a Web service discovery approach. The performance of matchmakers is calculated in terms of precision and recall. For any information retrieval (IR)-based approach including Web service discovery system, precision is a notion of correctness, whereas recall is a notion of completeness of the approach [10].

The number of available Web services has increased rapidly along with their growing popularity. In addition, the number of advertised Web services is expected to explode in the future [11]. The process of matching a request against the advertised Web services is very time consuming if there are a large number of Web services. However, existing approaches to Semantic Web service discovery focus more on improving and optimizing the performance of matchmaking process through reducing false results and disregard the mentioned challenge [12], [7], [13]. The problem with the current approaches is that they match a requested service with all of the published Web services in a repository. Thus, a huge repository drastically affects the execution time of the matchmaking process [14]. The query response time (QRT) of Web service discovery is used to measure the execution time and is defined as the elapsed time of a matchmaker to process a single request [8].

The general research question this research tries to answer is:

How to enhance matchmaking in order to improve the performance of Semantic Web service discovery?

In order to be able to answer this question, a set of research questions that address the problem in detail are defined, as follows:

1. What are the existing approaches and frameworks to Semantic Web service discovery?
2. How can the performance of Semantic Web service discovery be improved?
3. How can the query response time (QRT) of Semantic Web service discovery be improved?
4. How to implement and evaluate the improved Semantic Web service discovery in the Semantic Web service framework?

1.3 Objectives of the Study

The main objective of this research is contributing to the enhancement of the state-of-the-art approaches to Semantic Web service discovery. Based on the discussed problem statement, this research aims at the following detailed objectives:

1. To investigate the current Semantic Web service discovery approaches and frameworks for selecting the scope of study.
2. To improve the performance of Semantic Web service discovery.
3. To improve the query response time (QRT) of Semantic Web service discovery.
4. To implement and evaluate the improved Semantic Web service discovery in the selected Semantic Web service framework.

1.4 Scope of the Study

This research focuses on the semantic approaches to Web service discovery. The shaded boxes of Figure 1.1 outline the boundaries of this study.

From the components distribution perspective, software applications are categorized to 1-Tier (Centralized), 2-Tier (Client/Server), 3-Tier (Presentation/Business/Data), and N-Tier. In N-Tier architecture, “N” implies any number to show the distinct tiers used in the application. Breaking up an architecture into tiers provides a model for developers to create a flexible and reusable application. The SOA paradigm is an instance of N-tier architecture. This paradigm may be implemented using different technologies. Among these, Web service technology is considered as the most prominent instance to realize SOAs. It provides a way to integrate different applications by facilitating the interoperability between them.

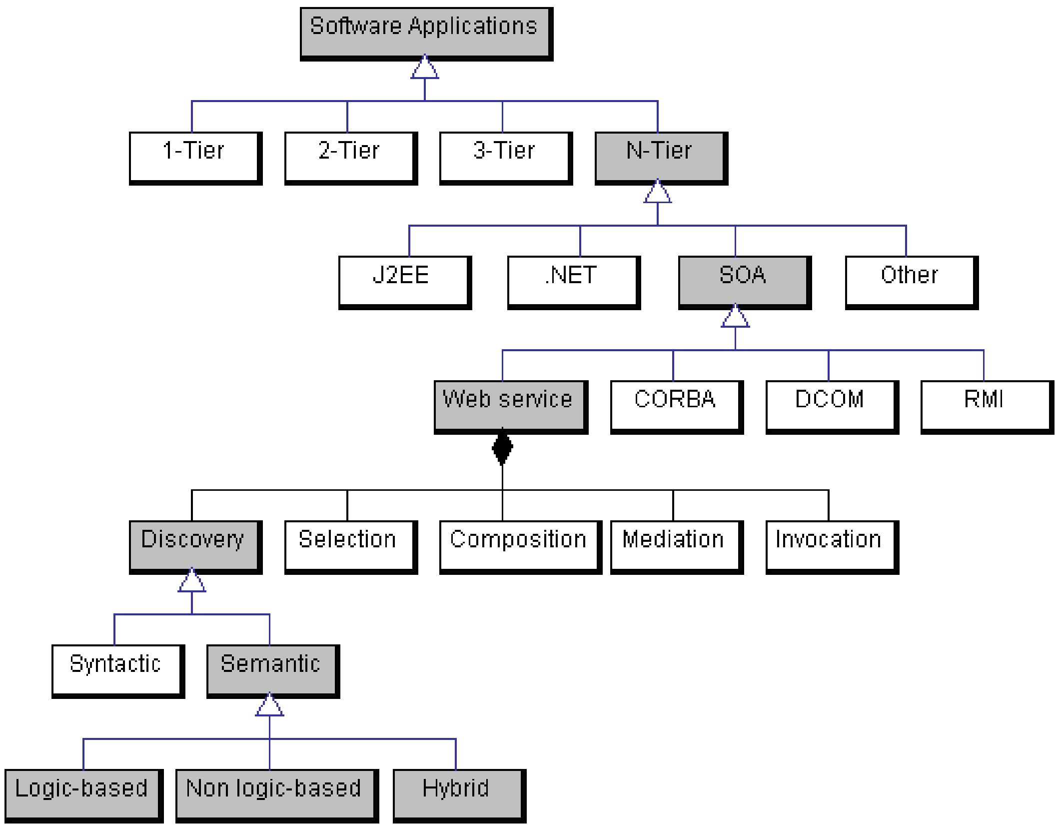

Figure 1.1 Scope of Research

One of the important usage tasks of Web services is their discovery as it is a compulsory prerequisite to every process concerning them. Web service discovery is categorized primarily to syntactic and semantic from the matchmaking perspective. Basically, the former is a simple keyword-based matching that is limited by the ambiguities of natural languages, whereas the latter relies on semantic descriptions to precisely match requests and Web services. Semantic Web service discovery aims to overcome the inadequacies of syntactic discovery and automate the process of matchmaking.

The approaches to Semantic Web service discovery are classified as Logic-based, Non-logic-based and Hybrid. While Logic-based approaches rely on logical reasoning, Non-logic-based approaches employ such techniques as graph matching, linguistics, data mining, or IR to perform matching between a pair of service descriptions. Hybrid approaches combine techniques from both of the aforementioned categories. This research aims to contribute to the improvement of the selected approaches from all of these categories. Thus, investigating the prominent techniques used in each category is in the scope of this study.

The performance of the proposed approaches would be evaluated in terms of precision and recall measures from IR field. It is because the Web service discovery is a kind of IR application [15]. Particularly, macro-averaged precision and recall metrics are applied to measure the performance of the proposed matchmaking algorithms and to compare them with other prominent approaches.

The number of available Web Services is growing rapidly because most enterprises are deploying their services on the Web [16]. It is expected that in the future, a huge number of services will be able to be consumed in the Web. As a higher number of services become available, there is a need for solutions that improve the execution time of Web service discovery [17]. The execution time of the proposed Semantic Web service discovery approaches would be evaluated in terms of QRT. Particularly, average QRT (AQRT) is used to measure the time spent by an approach on matching a set of requests [8].

1.5 Significance of the Study

With the aid of Web services, it should be possible for different applications to integrate and exchange information dynamically. Considering the fact that not all Web services follow a standardized format, the lack of semantics is a burden to make applications integrated automatically. Using semantics for describing the capabilities of Web services, transforms them to an unambiguous and machine-readable format thus enables their discovery, selection, composition and invocation, more intelligent. Each of these processes has attracted a vast number of recent research studies. Among those, Web service discovery is considered as the foremost and in contrast to others, an indispensable usage task. In particular, it affects service composition and invocation. Thus, it is considered as one of the main challenges in SOA research [18], [19].

Different aspects of service descriptions might be considered for their matching. As innovative approaches are employed for both annotating and retrieving those aspects, the improvement of service matchmaking is a continuous process. For instance, the annual international Semantic Service Selection (S3) contest is an initiative formed at the fifth International Semantic Web Conference (ISWC 2006) in Athens, USA which aims at encouraging the rapid and innovative development of tools for Semantic Web service matchmaking. In addition, this contest provides means for comparative evaluation of matchmakers for different service formalisms [8].

Nowadays, because most of the organizations are attempting to implement their Business-to-Business (B2B) and Business-to-Customer (B2C) transactions in the form of Web services, the number of available Web services has increased dramatically [16]. Due to this phenomenon, finding an appropriate Web service which is in agreement with the user's desire is a challenge that emphasizes the need for effective and efficient Web service discovery approaches [20], [21].

The process of Web Service discovery should return those services that fully or partially match with the requirement of a user. A weak discovery approach often omits some of all desired services or incorporates some of the irrelevant services. A considerable amount of research has targeted improving this process. However, there still is a lack of efficiency in Web service discovery. To realize the vision of automated service computing, particularly for composition and invocation of services, it is necessary to discover services which provide the requested capabilities in a very precise way [22].

1.6 Organization of Thesis

The remaining parts of this thesis are organized according to the following chapters:

Chapter 2 provides background information about the concepts involved in the scope of this study as well as the common aspects of Web service discovery architectures. In addition, the important frameworks for Semantic Web service are studied and compared. A taxonomy is provided to classify Web service discovery systems from various perspectives. This chapter also focuses on the literature of Semantic Web service discovery and categorizes the existing approaches. In addition, a set of characteristics is presented to classify the approaches to Semantic Web service discovery in more detail. Finally, some of the problems of the current Semantic Web service discovery approaches that affect their performance and QRT are recognized and explained.

Chapter 3 presents the methodology of this research. It includes the utilized research design and procedure as well as the research instrumentation. Furthermore, the data set and the metrics used for evaluation of the proposed approaches are described. Finally, research assumptions and limitations are enumerated.

Chapter 4 proposes a framework for Semantic Web service discovery. Central to this framework is a matching engine that integrates different approaches to realize an enhanced matchmaking. The components of this framework along with their interactions are then described. In addition, a Logic-based and a Non-logic-based matchmaker are proposed. For each matchmaker, various considered filters are explained. Feasibility of two statistics-based methods is then studied to weight and combine the results of Non-logic-based filters automatically. Independent from the matchmakers, a Pre-matching filter is proposed to speed up the process of discovery.

Chapter 5 presents an evaluation of the proposed approaches to Semantic Web service discovery. It first evaluates both the Logic-based and the Non-logic-based matchmakers, separately. This includes measuring the performance of individual filters of each of these matchmakers with respect to the considered data set. The experimental results of these evaluations are then thoroughly analyzed and a Hybrid matchmaker is proposed to overcome the shortcomings of the individual matching approaches. This Hybrid matchmaker is also compared with prominent matchmakers. Finally, the effect of applying Pre-matching filter on the response time of the proposed Hybrid matchmaker is evaluated.

Chapter 6 reports findings and contributions and draws conclusions of this thesis. In addition, it outlines suggestions for future works.

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