

# Understanding Web Service Discovery Goals

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**Abstract**— Articulating proper services search queries has been a challenging task for clients when searching for relevant Web services. Service discovery search results will not be improved unless we determine ways for correctly understanding client discovery goals. In this paper, we introduce a solution to this problem and perform a key study for understanding service discovery goals. We introduce the concept of Quality of Web Service (QWS) for our quality-driven ranking mechanism. Based on our study, we determine that service discovery goals can be defined as exploratory or informational. We further use these findings to demonstrate how the knowledge of service discovery goals are beneficial in improving the way clients perform service search queries. Results from our experiments are intriguing and show that the performance of informational service queries in terms of precision improves the querying process by 36.26% and 40.39% when compared to Google's PageRank and Yahoo, respectively. We further use our findings to provide insights on improving the service retrieval process.

**Keywords**—Discovery of Web Services, User Goals, Client Goals, SOA, Ranking, Service Discovery, UDDI, QoS, Quality.

## I. INTRODUCTION

The Web contains a vast pool of data that is of an unstructured nature. Finding specific pieces of information within such an incredible amount of data can become nearly impossible without powerful tools that can automate the discovery and searching over the Web [1]. Search engines help facilitate the finding of information over the Web much more efficiently. Although search engines have proven to be indispensable, searching on the Web may be limited by how well search engines can retrieve relevant information and how accurate they rank search results.

In addition, due to the fact that Web services are syntactically described using WSDL, current search engines and IR methods may not be completely suitable for finding relevant Web services. That is, searching for relevant Web services using current Web-based ranking algorithms that were specifically exploited for finding pertinent information within Web pages is inherently impractical primarily due to key differences that exist between Web services and Web pages.

Furthermore, the underlying goals of searching for information on the Web are relatively different from the goals of searching for services on the Web. For example, users searching on the Web often seek information about a particular topic by reading/viewing Web pages or obtaining a resource available on Web pages [2]. However, clients searching for Web services on the Web often seek service offerings about a particular domain of interest to be integrated into their systems. Furthermore, when discovering relevant Web services, clients look for services that not only can meet their requirements, but

are also capable of performing the required functionalities with an acceptable degree of quality of service (QoS) [3].

Because clients are more concerned with the degree to which Web services can accomplish the required functionality, discovering Web services using quality attributes combined with keyword-based methods becomes the natural solution. Therefore, associating quality of service for Web services may provide clients with ways to improve the service search process and to properly articulate service queries tailored to their needs. However, automatically identifying client goals when performing service search queries is a challenging task.

In this paper, we study how to automatically identify client goals in service discovery without any required feedback. To accomplish this task, we perform a survey study to assess the importance of quality-driven service discovery. Then, we propose potential service quality features for predicting client goals that can be used for ranking Web services. In particular, we make the following contributions:

- We examine the potential of associating quality of service for Web services. To accomplish this task, we conduct a survey study in which we asked 144 participants to indicate quality features that can potentially be used to identify client service discovery goals.
- We define a comprehensive set of non-functional properties for Web services. In particular, we define the appropriate QoS metrics for Web services, which we call QWS, and develop techniques to measure and assess the quality of service for Web services.
- We introduce a novel technique for efficiently querying and ranking Web services based on their QWS metrics.
- We evaluate the effectiveness of our proposed ranking technique and compare the results with other existing Web-search ranking methods.

The rest of this paper is organized as follows. Section 2 describes some of the related work. Section 3 describes client service needs and introduces the concept of the Quality of Web Service (QWS). Section 4 presents key statistical analysis and identifies client service query goals in service discovery based on a survey study that we have conducted. Performance evaluation of our query processing model is also discussed in Section 4. Finally conclusion and future work are discussed in Section 5.

## II. RELATED WORK

Although many of the research efforts that examined the user Web search behavior may help improve the search process, there has been few attempts on identifying the goals of

users when searching on the Web [4]. Broder in [5] defined different types of Web search including navigational, informational, and transactional. By categorizing user information needs when performing a Web search, then it is possible to identify user goals [5,6,7]. Identifying user goals when searching can significantly improve the ranking and clustering of search results [7,8,9].

At the Web services level, there has been little or no research in identifying client service discovery goals. However, there have been several research efforts to improve the discovery of Web services. In [10], the authors proposed a system that discovers Web services based on keyword search only which takes advantage of IR methodology utilizing the Vector Space Model (VSM). This approach computes the similarity between query terms and the document collection focusing mainly on WSDL operations (i.e. operation names). In a similar effort, the authors in [11] proposed Woogle, a search engine which focuses on retrieving WSDL operations. Woogle (which discontinued its services in 2006), collects services from accessible service registries and provide clients with capabilities to perform keyword-based search. However, the underlying goal for many of these solutions is based on the assumption that Web services belong to the same domain of interest and are equal in terms of their behavior in accomplishing the required functionality.

Assessing QoS for Web services is a fundamental step toward obtaining pertinent high-quality results. In an effort to regulate the quality of Web services, the authors in [12] proposed an extension to the current WSDL specification based on QoS ontology. The WS-Policy framework described general features, requirements, and capabilities of Web services [13]. In [14], the author provided a comprehensive list of QoS parameters that cover the quality in Web services.

Unfortunately, many of the existing approaches do not provide a way for clients to articulate proper service search queries tailored to their needs. In fact, existing solutions do not sufficiently consider end-to-end discovery mechanisms that can provide clients with quality Web services and help satisfy client service discovery goals. As part of this endeavor, we present in the following sections a mechanism that helps improve service discovery results by identifying client service discovery goals using quality attributes that can be extracted from existing Web services.

### III. CLIENT SERVICE NEEDS

The growing emphasis on techniques for discovering relevant Web services has dramatically increased the need for methods that let clients effectively find Web services that are tailored to their requirements. Such requirements can be functional (what the service offers) or nonfunctional (constraints on various properties such as quality of service, service reputation, interface semantics, and cost). Because many Web services will likely accomplish similar functionalities, determining the most suitable Web services without assessing their behavior under certain conditions will be challenging. Measuring the degrees to which Web services can perform the required functionality through a combination of QWS parameters becomes significant, particularly in distinguishing between services competing in the same domain.

Allowing clients to properly articulate service queries helps them make accurate decisions. For example, a developer who wishes to choose between various implementations of a Web service might be influenced by performance, reliability, and accessibility information. Consider the following sample service search queries for a particular keyword (i.e. “quotes”):

- *Find all Web services offered by business entity A that have response times greater than 390 ms and less than 500 ms.*
- *Find all binding templates of Web service A that have medium performance and SOAP faults between 10 and 15.*
- *Find all Web services that support HttpGet and SOAP 1.1*

Although these service queries might resemble simplicity when performing a search, current search methods either through service registries (i.e. Universal Description, Discovery and Integration - UDDI) or search engines can not fulfill the goals of clients executing these search statements for many reasons, most notably because they provide no Quality of Web Service (QWS) representation.

#### A. Assessing the Behavior of Web Services

One of the basic usages of Web services consists of invoking operations via sending and receiving messages. Clients or complex applications accessing diverse Web services would require advanced features to evaluate or assess these Web services prior to any potential interaction. Assessing the behavior of Web services is often neglected by service discovery protocols. As more Web services become available, a large number of Web services would compete in offering similar functionalities (i.e. different real-time stock providers). However, Web services differ in how these functionalities are offered (i.e. input and output data types), and more importantly the conditions to which clients make use of them (i.e. quality of Web services).

One of the key elements driving the popularity of Web pages is through the linking structure (i.e. Web graphs). However, Web services do not have the linking capability. Therefore, an alternative to drive the overall popularity and usefulness of Web services is through the conditions at which Web services offer their functionalities, or the Quality of Web Service (QWS).

Integrating QWS into the discovery process, or a quality-driven discovery, becomes a crucial element in differentiating between Web services that share similar functionalities and offers a way to measure or assess their behavior. We identify the quality measures for Web services as advertised or observed. Advertised quality metrics are those that are published by the service provider in public registries, related Web content, or directly shared with clients. Enabling service providers to provide their own claims may provide room for manipulation. In addition, when considering Web services, clients are primarily interested in the perceived quality. Observed quality characterizes the quality of Web services in delivering the intended functionality. That is, observed quality provides a quality measure as perceived by the client. In this work, we consider QWS metrics perceived by the client, or the observed quality, via a trusted service broker, or our Web Service Broker (WSB) [15].

## B. QWS Parameters

The quality of Web service will become a significant differentiator between all of the competing implementations. To that respect, the quality of service for Web services must transcend system-centric quality measures to encapsulate not only implementation details that may influence metrics (i.e. performance) but also deployment and user experience issues.

Although the level to which stringent quality of Web service client requirements may vary, a set of quality of Web service parameters that can provide an overall assessment of the Web service's behavior in performing the required functionality is critical. However, what type of Quality of Web Service (QWS) metrics are deemed to be critical when making selection decisions and how will clients be able to select the most suitable or right Web service?

**Definition 1 (Quality of Web Service - QWS).** We define QWS as a measure of the degree to which a Web service can perform the required functionality for one or more given parameters.

When considering QWS, we mainly focus on those QWS parameters that are broad or generic enough (i.e. non service-specific) to cover a wide range of applications or domains. That is, we consider QWS parameters that are generic enough to be used across all Web services, and across all domains.

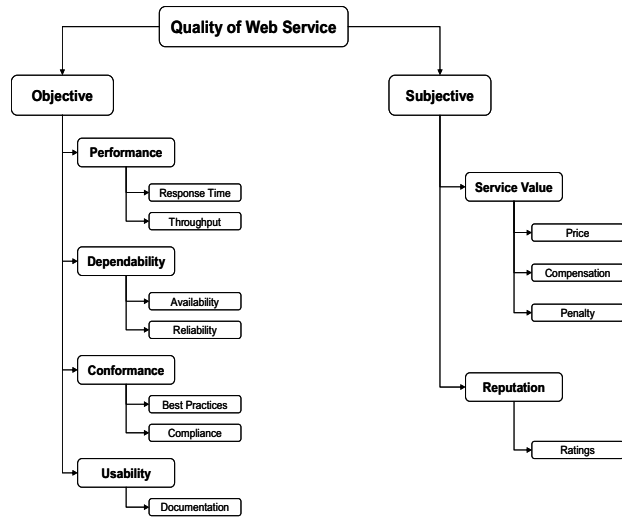


Figure 1. Basic QWS parameters

As shown in Figure 1, we characterize QWS parameters into two groups: (1) objective, and (2) subjective. Objective QWS are those parameters that correspond to measurements that are concrete, or quantitative. On the other hand, subjective parameters correspond to the qualitative measures which can be either based on the client's perception or regulated by the service provider. For the purpose of this paper, we only consider objective QWS. Objective QWS are numerical and quantitative metrics that can be measured directly as a result of invoking a Web service as perceived by a client.

**Response Time ( $QWS_{rt}$ ):** Response time is the time taken to send a request and receiving a response. It represents the

processing time taken by a Web service to handle a given request and does not include any time delay or latency. The response time is service provider specific and can be calculated using the following equation:

$$QWS_{rt} = RT_c - RT_r \quad (1)$$

where  $RT_c$  represents the time a response is received and  $RT_r$  represents the time the actual request has taken place.

**Maximum Throughput ( $QWS_{tp}$ ):** Maximum throughput is the maximum number of requests that can be handled or processed at a given unit time. It can be calculated using the following equation:

$$QWS_{tp} = \frac{Req_c}{T_s} \quad (2)$$

where  $Req_c$  represents the total number of requests completed, and  $T_s$  represents the unit time (e.g. 1 minute).

**Availability ( $QWS_{av}$ ):** Availability is defined as the ratio of the time period when the Web service is available or ready for use. It can be calculated using the following equation:

$$QWS_{av} = \frac{upTime}{totalTime} \quad (3)$$

where  $upTime$  represents the time the system exists during the interval of time when the measurement is taking place, and the  $totalTime$  represents the addition of the  $upTime$  and the  $downTime$ . The  $downTime$  represents the time the system has been unavailable during the interval of time when the measurement is taking place.

**Reliability ( $QWS_{rb}$ ):** Reliability defines the ability of a Web service to perform the requested functionality. It is based on the number of successful invocations during the period at which the measurement is taking place. It can be calculated using the following equation:

$$QWS_{rb} = \frac{R_f}{Total_{req}} \quad (4)$$

where  $R_f$  represents the number of requests the service was able to perform the requested functionality successfully, and  $Total_{req}$  represents the total number of requests.

**Documentation ( $QWS_{dc}$ ):** Documentation defines the extent to which a Web service interface contains an adequate level of documentation. That is, the amount of textual documentation in description tags including service, port, and operations. It can be calculated using the following equation:

$$QWS_{dc} = \frac{WSDL_{doc}}{WSDL_{total}} \quad (5)$$

where  $WSDL_{doc}$  represents the total number of documented tags (e.g. tags containing textual data) and  $WSDL_{total}$  represents the total number of tags that can be documented (e.g. can have documentation tags).

**Best Practices:** Best Practices measures the degree to which a Web service is conformant with WS-I profile guidelines [16]. It can be calculated using the following equation:

$$QWS_{bp} = \left( \frac{BP_{pass}}{BP_{total}} \right) \times 100 \quad (6)$$

where  $BP_{pass}$  represents the number of tests that a Web service has passed during an evaluation, and  $BP_{total}$  is the total number of tests conducted for measuring the best practice.

**Compliance:** Compliance measures the degree to which a WSDL is conformant with the Web Services Description Language (WSDL) specification. This includes validating WSDL syntax (e.g. well-formed), validating against schemas, import and binding rules. It can be calculated using the following equation:

$$QWS_{cp} = \left( \frac{CP_{pass}}{CP_{total}} \right) \times 100 \quad (7)$$

where  $CP_{pass}$  represents the number of tests that a Web service has passed during an evaluation, and  $CP_{total}$  is the total number of tests conducted for measuring the compliance practice.

#### IV. RESULTS

In this section we present results and statistics that will help us assess the importance of a quality-driven service discovery. As part of this work, we used a subset of our Web Service Crawler Engine (WSCE)'s repository [17,18] containing 14,562 Web services collected from various Web resources to perform our analysis and performance evaluation. We also used our QWS Manager (QWSMan) to continuously monitor the behavior of the collected Web services for all of the QWS parameters discussed in Section 4.2 using commercial benchmark tools [19]. In an effort to help the Web service research community, we provide a downloadable copy of a subset of the dataset that we used for this paper [20].

##### A. Identifying Client Service Query Goals

At the Web level, several research studies have been conducted on identifying the goal of users during a Web search in which the goal is used to improve the page ranking and answer presentation [21]. As part of this endeavor, we conducted a survey to determine the goals of clients when discovering Web services.

Designing a survey is a crucial element in collecting reliable results for our survey. Therefore, we first evaluated the appropriateness to directly determine the degree of complexity for query variations with respect to QWS. For this purpose, we ask participants to become acquainted with the concept of QWS [18,19], determine the goal of the user and then ask three questions relating to: (1) types of service discovery goals, (2) quality-driven discovery goals, and (3) QWS parameters variations. The survey was conducted between February 26th and March 26th, 2008 and consisted of 144 eligible participants.

Participants of our survey included CS graduate students and academic faculty members from twenty nine different institutions who are proficient in the area of service discovery. As part of the design of our survey, we asked participants a series of preliminary questions that demonstrate their knowledge in the area of service discovery. We considered all of the surveys since all of the participants were considered proficient.

##### 1) Overview of Client Service Query Goals

As part of our survey design, we decided that it is important to determine the types of clients query goals in service discovery. The aim of this question is to determine a high-level overview of the client service discovery goals (generic client goals). Participants were asked to answer a question that relates to the importance of associating quality attributes in the service discovery process. Results from this survey question demonstrate that the majority of our survey participants strongly believe that quality-driven service discovery is important and that keyword-based queries are not suitable enough. Based on these results, we determine that client service discovery goals can be grouped into at least two main categories: exploratory (16%), and informational (84%).

**Definition 2 (Exploratory Client Goal).** A query is considered exploratory when a client wants to find any or explore all Web services about a particular domain or interest without having any QWS criteria in mind.

**Definition 3 (Informational Client Goal).** A query is considered informational when a client wants to find any or explore all Web services about a particular domain or interest with associating QWS information.

For exploratory queries, clients typically presume that any Web service to be the "best" answer (i.e. similar to Google's "I am Feeling Lucky" feature) and they are willing to discover multiple results. However, using information queries, clients typically presume that not all Web services that match a query term can be considered to be the "best" answer and they are willing to discover only quality results.

Based on the results from our survey study we can conclude that the majority of clients believe that exploratory queries (i.e. without QWS consideration) may not be efficient. In fact, 84% of our survey participants believe that informational queries (i.e. with QWS consideration) are likely to yield Web service search results that satisfy client service needs.

Since the perception of quality may vary significantly, we can identify the top criteria that clients believe can best express informational service queries. These criteria can then be represented by the level of importance for each QWS parameter. The results from this survey question help us to identify the types of information query goals.

##### 2) Informational Client Service Query Goals

The main difference between exploratory and informational client service query goals is the degree of converge about a particular domain of interest. That is, clients of informational queries have a focused goal on obtaining Web services that meet their QWS criteria. However, the degree of focus can vary significantly from one client to another and may depend on the context that a particular Web service's functionality can perform. For this purpose, we designed our survey to consider this type of client goals and asked participants to rank a set of QWS attributes.

Based on the results from this survey question, we determine that informational query goals can be further classified as: (1) undirected, (2) semi-directed, and (3) directed. As clients' search criteria become more specific, the

search query becomes more focused. That is, the level of strictness from undirected to directed increases. For example, clients of directed informational queries typically have particular QWS criteria in mind and they consider varying the degrees of importance of QWS parameters essential.

Undirected informational goal deals with clients whose quality information needs are not specific and clients in principle consider all of QWS parameters of equal importance. By asking undirected informational queries, clients look for those Web services that are high quality but do not rank QWS parameters based on any order or according to any preference. Undirected informational queries are the closest to the exploratory queries since they treat all QWS parameters of equal importance.

Results from our survey study show that clients of directed informational queries have QWS variations that are different from those of semi-directed informational queries as shown in Figure 2. Based on the results presented in Figure 2, we conclude that response time and availability are considered the top most important QWS parameters. As shown in Figure 2, client goals of the directed informational queries are different from semi-directed queries with respect to QWS parameters. For example, directed informational query goals put the focus on performance QWS parameters (i.e. response time and throughput) by 44.5% while semi-directed query goals are less specific in terms of performance QWS parameters which constitute 32.7% of the overall importance.

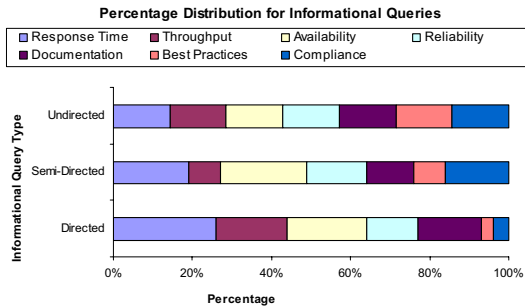


Figure 2. Informational Query Goals Percentage Distribution

### B. Query Processing and Ranking

Results from Section 4(A) demonstrate that clients can significantly be influenced by service query variations. In this respect, we built a query processing and ranking module that extends our WSB framework [15,18,19] and accommodates the findings of our survey study. We implemented two main algorithms: (1) KRank representing exploratory queries, and (2) QRank representing informational queries.

For exploratory queries, we process queries and rank Web services based on keyword matching techniques without considering their behavior. For informational queries, clients can integrate QWS parameters over how service queries are processed. In this case, clients may also wish to specify as part of quality-driven service queries those QWS parameters that they consider important, and their level of importance. This can be achieved by assigning weights ranging from 0 to 1 for each QWS parameter. The results from Figure 2 can be used as

control variables for the QRank algorithm. Table 1 presents a summary of the two ranking algorithms that we used for this study. More information about our KRank and QRank algorithms can be found in [19]. In addition, we extended QWS settings for the QRank algorithm to accommodate the results exhibited in Figure 2.

TABLE I. SUMMARY OF THE WSB'S RANKING ALGORITHMS

Algorithm	Description
KRank	KRank processes service search queries without taking into consideration any QWS metrics (non-quality-driven). KRank represents exploratory queries.
QRank	QRank processes service search queries with taking into consideration QWS metrics (quality-driven). QRank represents informational queries.

We used the undirected informational query, which we refer to as QRank<sub>U</sub>, to perform our performance evaluation with exploratory and other Web-based methods since it treats all QWS parameters the same and is not QWS parameter specific. Service search queries used for our evaluation are selected as a subset of Zeng et al. and Jansen et al. search query test suites which are based on actual user search studies [22, 23]. Relevance judgments were obtained from five different judges who were carefully selected based on a questionnaire and who are considered proficient in the areas of service discovery and ranking algorithms. The process was voluntary and included faculty members/CS graduate students.

Judges were presented search results in printed documents. A relevance judgment document consists of judging the top fifteen search results for ten queries where there are 150 items (15\*10=150) to be judged for each result set. Relevance judgments were obtained for the KRank, QRank<sub>U</sub>, Google and Yahoo search results. Once a judgment is finished, the relevance judgment documents are gathered and data is collected. We applied TREC's pooling method to test our ranking algorithms.

### C. KRank versus QRank<sub>U</sub>

The main difference between exploratory (or KRank) and undirected informational (or QRank<sub>U</sub>) search results is the integration of QWS parameters into the ranking process. For this purpose, we would like to compare the performance in terms of precision and recall for KRank and QRank<sub>U</sub> query goals. The recall-precision curves for the 11 standard cut-off recall levels for ten queries for KRank and QRank<sub>U</sub> query goals are shown in Figure 3.

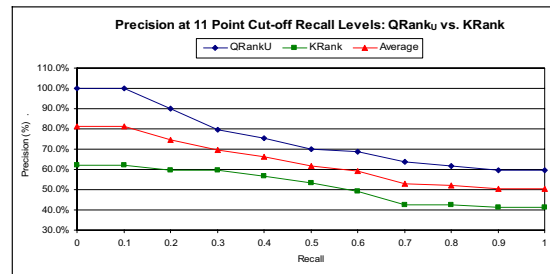


Figure 3. Average recall-precision curves of ten queries for exploratory and informational undirected

Results from Figure 3 show that QRank<sub>U</sub>'s recall-precision curve outperforms that of KRank. That is, integrating QWS parameters into service discovery significantly improves the service retrieval and ranking process. We observe an average improvement of 23.53% using QRank<sub>U</sub> over KRank service queries. This percentage represents an increase in the level of precision which indicates that the ranking strategy has improved by approximately 24% and that QRank<sub>U</sub> service discovery provides a better mechanism for clients to articulate proper service queries tailored to their needs.

#### D. QRank<sub>U</sub> versus Other Methods

Having average recall-precision curves are very useful for performing comparative analysis of distinct ranking algorithms over a set of queries. To that respect, we compare the performance of the informational service queries with other Web-based ranking methods including Google and Yahoo. Results from this test are shown in Figure 4.

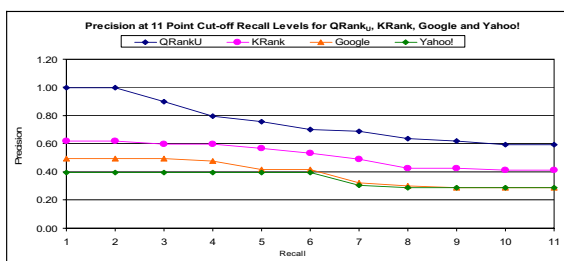


Figure 4. Average recall-precision curves of Informational Undirected (QRank<sub>U</sub>), Exploratory (KRank), Google and Yahoo

As shown in Figure 4, QRank<sub>U</sub> has the best performance amongst all other ranking methods. Figure 4 also shows that the difference in performance between non-quality and quality-driven retrieval methods is observable by the difference between precision values for Google and Yahoo which have very similar precision versus recall curves. Based on these results, we can conclude that incorporating QWS into the service discovery process results in ranking that significantly outperforms current ranking methods.

Figure 4 also shows that KRank algorithm outperforms Web search engines since search results only include Web service related information while search engines provide a combination of Web service related information in addition to Web pages (e.g. Web-based search engines treat Web services as Web pages). Based on these findings, we can conclude that by the filtering phases employed by WSCE [5,18] have been indispensable in increasing the accuracy in finding Web services.

#### V. CONCLUSION

Results from our study show that service discovery goals can be classified as exploratory or informational. We also determined that informational service queries can be further defined as directed, semi-directed, and undirected. Results from our experiments show that our exploratory algorithm outperforms Web-based methods by 16.86%. Results also show that our informational algorithm significantly improves the service discovery process by 36.26%, and 40.39% when

compared to Google's PageRank and Yahoo, respectively. Based on these results, we conclude that integrating quality attributes into the discovery process is inevitable and will likely yield results that satisfy client service needs when performing a Web service search. For future work, we plan to include additional ranking strategies and investigate the use of other QWS parameters such as cost, and reputation.

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