



A novel non-functional matchmaking approach between fuzzy user queries and real world web services based on rough sets



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HIGHLIGHTS

- We propose in this paper a new matchmaking approach between user queries and real world Web services.
- It consists in generating fuzzy core classification rules of Web services to predefined categories.
- These rules leverage core attributes from the dataset, which are computed using rough sets theory.
- The fuzzy user query is then matched against the established core rules.
- The retrieved services are then ranked according to their distances to the user query.

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ABSTRACT

We propose in this paper a novel matchmaking approach between fuzzy user queries and real world Web services. The matchmaking spans over a domain dependent classification step that produces fuzzy classification rules for Web services. The elaborated rules leverage a core set of non-functional quality attributes, which is extracted using rough sets theory. Furthermore, these rules are leveraged to classify Web services into categories, which allows reducing the matchmaking space. The experimental results show that our proposed matchmaking approach provides good results in terms of efficiency and precision.

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1. Introduction

The growing deployment and success of Web services made people more and more interested in using extensively this technology. Web services are announced and published by service providers through dedicated registries such as Universal Description Discovery and Integration (UDDI) registries. They are searched by users based on discovery protocols, portals or search engines, which perform matchmaking between user queries and Web services. From a Web services engineering perspective, matchmaking is one of the essential duties in elaborating discovery and composition mechanisms, which allows service providers to fulfill service consumer queries. It is considered as a search or discovery problem wherein service consumers attempt to find a list of

matching Web services, which have the same functionality, i.e., belong to the same domain, in order to accomplish their tasks. This list may contain more than one service, which makes the selection of the best one an issue. Several research initiatives were undertaken to provide a Quality of Service (QoS) driven matchmaking for Web services and to refine the search results. These initiatives formulate the user query as a set of constraints over the non-functional quality attributes. Such constraints may be vague due to a possible user lack of knowledge about the exact values of quality attributes. Accordingly, a plethora of fuzzy based query specification approaches was devised [1–6] to capture such constraints. In these works, user preferences about quality attributes are specified using linguistic terms such as “high”, “medium”, “low”, etc. These linguistic terms allow specifying imprecise constraints over quality attributes. For instance, the user can look for a commerce Web service, which has a very high reliability and average response time. Fuzzy non-functional matchmaking approaches have some shortcomings. First, despite allowing the specification of imprecise constraints, they do not solve the user lack of

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knowledge issue. For instance, the user is not necessarily aware of the most relevant attributes in each domain of services and so the search may not lead to the best results he expects. Second, the search is done on all the services, which can lead to a performance issue. Such issue is raised even when the Web services are clustered in domains since the clustering is based on functional aspects of Web services rather than the non-functional ones. Henceforth, a novel matchmaking approach is needed. We alleviate in this paper the aforementioned challenges by first determining the most relevant quality attributes for real world Web service domains. These attributes are then leveraged to build core classification rules of Web services in categories, which allow reducing the matchmaking search time.

The main contributions of this work are three-fold:

- The proposal of a rough sets based approach for extracting most relevant quality attributes in real world Web service domains.
- The elaboration of a classification approach that provides fuzzy classification rules for Web services based on non-functional quality attributes.
- The design and implementation of a novel fuzzy non-functional matchmaking algorithm between user queries and real world Web services. The proposed matchmaking algorithm improves the basic matchmaking algorithm using fuzzy classification rules.

The remainder of the paper is organized as follows. Section 2 presents the related work regarding Web service matchmaking approaches. The required background to understand the proposed approach is provided in Section 3. Both, rough sets and fuzzy logic are covered in that part of the paper. Section 4 is dedicated to the presentation of our matchmaking architecture and the technical details related to the matchmaking process. In Section 5, experimental results and analyses are provided. Finally, some conclusions and future research directions are drawn in Section 6.

2. Related work

Matchmaking Web services to user queries has been extensively studied from a semantic perspective [7–10]. Semantic matchmaking can be achieved through the matching of Web service operation names and descriptions to user queries using supervised or unsupervised classification techniques. The semantic matchmaking allows to retrieve services that have a similar functionality to a user query. These services are ranked according to the similarity degree. However, such similarity cannot provide the user with a good feedback about best matching Web services in terms of quality. Accordingly, there is a growing interest in devising techniques for matchmaking based on non-functional quality attributes. We review in what follows research initiatives related to non-functional matchmaking. Sun et al. [11] suggested to expand the role of the Web Services registrar to include Quality of Service (QoS) assessment and Web Services syndication. Syndication means that a registrar, with the capability of identifying user's QoS preferences, could make recommendations and/or provide a package of Web Services to the user. This process turned the passive registrar into an active player. However, it suffers from the suspected impartiality of the registrar. One of the major issues in the matchmaking process is that QoS attributes are not easy to measure due to their complexity and the involvement of consumer's vague perceptions of QoS. To solve this issue, some proposed solutions leverage linear programming and optimal research technologies [12–14] to perform the matchmaking. These solutions are not convenient for non-functional properties that are not easy to be quantified in numerical form. Accordingly, a plethora of fuzzy-based QoS matchmaking approaches was devised to get

around this problem. Huang et al. [2,15] proposed multi-agent approaches with fuzzy group decision making methods to assist service providers and consumers in discovering appropriate services with consideration of their expectations and preferences. Chao et al. [1] proposed a framework, which leverages fuzzy logic to abstract and classify the underlying data of Web services as fuzzy terms and rules. The aim is to increase the efficiency of Web services discovery and allow the use of imprecise or vague terms at the level of the search query. Ragone et al. [16] devised an approach for the matchmaking of peer entities in electronic marketplaces, which mixes in a formal way Datalog (a declarative language based on Horn clause logic), fuzzy sets and utility theory, in order to determine the most promising matches between prospective counterparts. In [6], Lin et al. designed a model of consumer-centric QoS-aware selection called QCMA (QoS Consensus Moderation Approach) to analyze the group consensus based on their fuzzy opinion similarity and QoS preference with a number of QoS properties. In [17], a new decision model under vague perceptions of criteria was suggested. The proposed approach enables decision makers to select QoS aware services from the marketplace. The vagueness is captured using intuitionistic fuzzy sets (IFS). The proposed approach not only deals with decision makers' imprecise perceptions under incomplete information, but also objectively determines the relative importance of QoS criteria. Lately, a synthetic service selection method for ranking services is proposed in [18]. In this method, QoS metrics that are represented by linguistic, interval and fuzzy numbers are transformed into precise numbers. The objective weights of quality attributes, which are derived from an improved entropy model, and subjective weights, which are provided by the user, are integrated linearly into a synthetic weight. These weights are leveraged to perform the ranking of candidate services.

Despite the aforementioned interesting works towards using fuzzy logic in the matchmaking process, traditional matchmaking approaches did not investigate deeply how to identify core QoS quality attributes and explore the relative importance of these core attributes automatically or systematically to enhance the matchmaking process. Another drawback of published matchmaking works such as [19] is that they relied on synthetic data rather than real data. Conducting experiments on real data would provide more realistic results and conclusions. To the best of our knowledge, our work is the first that combines rough sets and fuzzy logic to establish a new matchmaking process between user queries and Web services. Furthermore, the work presents a deep analysis of the matchmaking process on a dataset of real world Web services. More precisely, we propose in this paper a novel matchmaking approach that is based on the extraction of most relevant non-functional quality attributes using rough sets theory. Rough sets [20] is a well-known technique for the computation of core reducts of information systems. Based on the extracted core attributes, we build a classification process, which allows grouping Web services in categories. This process spans over a core set of classification rules in which constraints over quality attributes are captured using fuzzy logic. Fuzzy logic [21] is a well-established technique for the specification of vague and imprecise constraints. The proposed matchmaking approach consists in matching fuzzy user queries to the established core classification rules. Furthermore, we conduct our experiments on QWS [22], which is a dataset of real world Web services. We provide also a performance analysis of our matchmaking approach compared to the basic matchmaking approach and also to a matchmaking approach, which leverages decision trees.

3. Background: fuzzy logic & rough sets

To grasp the underpinning of our proposed approach, we provide in what follows the required background related to fuzzy logic and rough sets.

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