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A new fuzzy hybrid technique for ranking real world Web services

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ABSTRACT

We propose in this article a new fuzzy hybrid ranking technique, which is based on a linear combination of two new ranking techniques we devised: an objective Fuzzy Distance Correlation Ranking Technique (*FDCRT*) and a subjective Fuzzy Interval-based Ranking Technique (*FSIRT*). The objective technique leverages the distance correlation metric to derive weights of quality attributes directly from the available data. The subjective technique computes weights from opinions of domain experts, which are specified via two ingredients: intervals representing acceptable ranges of values for quality attributes and importance values of a quality attribute with respect to the other attributes. We show that the linear combination of these two techniques allows to overcome the shortcomings of objective and subjective techniques. Our experiments are performed on a dataset of real world Web services. The empirical results show that a tuning of the proposed linear combination gives better ranking results than Entropy and Fuzzy AHP separately and even than a linear combination of these two well-known techniques.

1. Introduction

Nowadays, Web services are considered one of the most successful and popular technologies thanks to their contribution to the deployment of legacy systems through the internet and their convenience for the development of loosely coupled applications. The drastic growing of the deployed Web services made the selection of best Web services an issue for the consumers. In fact, several Web services are similar in functionality, which requires a mechanism for ranking them. Such a mechanism can be based on non-functional quality attributes such as response time, reliability, availability, throughput, and security. Depending on the domain of application, quality attributes may have different weights. Such weights are paramount for ranking Web services. Several ranking techniques were proposed to determine attribute weights. They are classified in three major categories: objective, subjective, and hybrid techniques. Objective techniques [19,20,22,24,26,37] determine weights directly from the data. Well-known techniques of this category are: principal element analysis, entropy, and multiple objective programming model. Subjective techniques [13,15,16,23,33] derive quality attribute weights from preference information given by domain experts. This second category includes well-known techniques such as Analytic Hierarchy Process (AHP), eigenvector technique, weighted least square technique, and Delphi technique. The last category is a hybrid combination of objective and subjective techniques [14,17,28,30,32,34,35,38]. Algorithms using the hybrid techniques determine weights directly from the data as well as from the preference information given by domain experts or the users.

It is well-known that objective techniques do not take into consideration the opinions of experts. This leads sometimes to unrealistic or biased results for some domains of application since the automatic collection of data is done at a precise time period and for specific candidates. Besides, regarding Web services there are some attributes that cannot be accurately measured such as security, and flexibility. On the other hand, weights determined by subjective techniques reflect the subjective judgement of domain experts. However, analytical results or ranking of alternatives based on such weights can be influenced by the decision maker due to his/her lack of expertise.

To overcome shortcomings of both objective and subjective techniques, we propose a fuzzy hybrid ranking technique that is a linear combination of a new fuzzy objective technique called *FDCRT* and a new fuzzy subjective technique called *FSIRT* that we devised. Both techniques are based on fuzzy theory in order to deal with imprecise Quality Of Service (QoS) constraints and opinions of experts. The experiments are performed on a dataset of real world Web services. They show that the combination of these two techniques provides better ranking results than Entropy and Fuzzy AHP separately or combined together.

The remainder of this article is organized as follows. Section 2 explores the related work. Section 3 provides background knowledge about fuzzy logic. Section 4 presents the new fuzzy objective

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technique (*FDCRT*) we propose while Section 5 is dedicated to the presentation of the new fuzzy subjective one (*FSIRT*). A new hybrid technique that is a combination of objective and subjective techniques is proposed in Section 6. In Section 7, we present our experimental design and we provide our experimental results and analysis in Section 8. Finally, the conclusion and future work are given in Section 9.

2. Related work

We review in this section the related work regarding objective, subjective and hybrid techniques for ranking Web services with a special focus on those using Fuzzy logic.

2.1. Objective techniques

In [19], the authors modeled QoS-based service selection as a fuzzy Multiple Criteria Decision Making (MCDM) problem. QoS criteria are specified using a set of linguistic terms such as *good*, and *poor*. Web services selection is performed in three steps. First, the fuzzy judgment matrix is built using a triangular membership function and the suggested expert QoS weights are defuzzified then normalized. Second, entropy weights are computed from the judgment matrix based on the entropy technique. Finally, the overall weights for the QoS criteria are obtained by a linear combination between expert and entropy weights.

In [20], the authors developed a MCDM methodology for QoS-based Web services selection. The purpose of this work is to capture imprecise QoS constraints and consider weighted experts' fuzzy opinions. Each expert provides ratings for alternative services with respect to each QoS attribute. These ratings are represented by trapezoidal fuzzy numbers and they are aggregated to form group ratings. The selection is performed via two steps namely defuzzification and ranking. The defuzzification is based on a fuzzy scoring approach, which transforms group ratings into a decision matrix containing only crisp data. This decision matrix is leveraged to derive attribute weights, which are used to rank Web services.

In [26], the authors proposed a QoS evaluation algorithm for Web services ranking based on Artificial Neural Network (ANN). The attribute weights are derived directly from the data based on Principal Component Analysis (PCA). The weights are then adjusted using ANN. Such adjustment is needed to cope with user's preferences. The output of the ANN is leveraged to rank Web services.

In [36], the authors classified Web services according to theirs similarity and then designed a QoS tree to manage the QoS that classified Web services. By querying the managed QoS, they proposed a QoS-aware Web service composition via a particle swarm optimization algorithm to perform fast Web services composition.

In order to solve the selection of secure Web services in a global and flexible manner, the authors in [37] introduced a Fuzzy logic method. They presented a stride model based evaluation of Web service security using quality of protection parameters like spoofing, tampering, reputation, information disclosure, denial of service and elevation of privileges.

2.2. Subjective techniques

The authors in [13] modeled Web services selection as a fuzzy MCDM problem and use triangular fuzzy numbers to represent imprecise QoS criteria. Some evaluators assess Web service performance using fuzzy sets, which are combined using the geometric mean method in order to build the aggregated fuzzy performance matrix [4]. This matrix and the fuzzy weight vector are then combined to determine fuzzy values for ranking Web services. Finally, the overall fuzzy ranking values of Web services are defuzzified using the center of area method in order to rank these Web services.

In [15], the selection of Web services for the sake of composition was formalized as a fuzzy constraint satisfaction problem. QoS preferences of users are represented by fuzzy expressions related by the AND logical operator while the different alternatives between QoS properties are connected through the OR logical operator.

The authors in [29] proposed a FMG-QCMA (Fuzzy Multi-Groups based QoS Consensus Moderation Approach) to meet the requirements of Web service consumers. The approach solves possible conflicts between group opinions in order to reach a consensus in selecting Web services. The proposed approach is also evaluated through a simple case study to demonstrate its effectiveness and efficiency.

In [33], the authors addressed the problem of expressing Web service user preferences in a semantic context. They analyzed the existing QoS ontologies and extended the OWL-Q ontology to capture trade-off preferences expressed using conditional lexicographic approach for QoS preference specification.

2.3. Hybrid techniques

In [17], a group of evaluators gave ratings for Web services based on crisp or fuzzy values. These values are then aggregated to form a performance rating matrix. This matrix is then normalized and used to compute normalized weights of QoS criteria based on the maximum entropy technique. The overall ranking of Web services is then computed using the fuzzy simple additive weighting method.

The authors in [30] proposed a ranking model for Web services based on synthetic weights which are the result of a combination between entropy-based objective and subjective weights, which are derived from users' preferences. The authors provide a small-scale simulation experiment for ranking Web services in which they illustrate their ranking technique.

In [32], the authors proposed a fuzzy integral combined with a fitness fusion to induce features and consequently reveal the decomposed information empirically illustrating the dominance benchmark and the fusion effect for approximations. The intent of their work is to search the maximal agreement between the objective evidences and the subjective expectations.

The authors in [34] proposed a new fuzzy rule based algorithm for selecting and composing Web services with respect to the users' preference using open source software. In a similar attempt, a formal service composition architecture for service selection is proposed [35], where the authors suggested a trust evaluation method for the service composition plan based on the subjective probability theory. The trust-oriented genetic algorithm (TOGA) is proposed to find a near-optimal services composition plan with QoS constraints.

Lately, in [38], the authors proposed a context-aware cloud service selection model based on the comparison and aggregation of subjective assessment extracted from cloud user feedback and objective assessment from quantitative performance testing. Also, objective assessment provided by some professional testing parties is used as a benchmark to filter out potentially biased subjective assessment from cloud users, then objective assessment and subjective assessment are aggregated to evaluate the overall performance of cloud services according to potential cloud users' personalized requests. This work is similar to ours, however they experimented only three attributes and tested only 59 Web services.

There are four main shortcomings of the related work on techniques for ranking Web services, which we consider in this work: