Web Service Selection Based on Integrated QoS Assesment

Olga Georgieva, Dessislava Petrova-Antonova
Department of Software Engineering
FMI, Sofia University "St. Kl. Ohridski"
Sofia, Bulgaria
e-mail: o.georgieva@fmi.uni-sofia.bg, d.petrova@fmi.uni-sofia.bg

***Abstract*—Currently, web services are the preferred technology for implementation of distributed applications that follow a Service-Oriented Architecture. The promise of reduced cost and time for enabling a large range of company-wide business processes shifts the research focus towards reasoning about web service selection. This paper proposes an approach facilitating clients to select a web service among several ones with the same functionality based on their quality of service (QoS) properties. It provides a mechanism for integrated QoS assessment of web services taking into account all measured QoS properties of the client's interest. The method estimates the strength of the mutual dependency of the QoS properties using a data set analysis of QoS values accumulated during the web service invocation. The approach is summarized in a step-by-step assessment procedure and is proved through a real web service selection scenario.**

Keywords-Web services; Quality of service; Web service selection; Theory of fuzzy sets; Probability theory.

I. INTRODUCTION

Nowadays, the Service-Oriented Architecture is the most commonly used paradigm for development of distributed software systems, especially in the context of cloud computing. Since the web services are one of the fundamental technologies used in the cloud, the problems related to their quality remain of primary importance. Thus, many research efforts are still focused on the development of new approaches for quality of service (QoS) assessment.

A. Problem formulation

The web service selection is a challenging problem especially when different web services provide equal functionality [8]. The clients aim to use the web services having the best quality, but the selection procedure meets several difficulties as follows:

- The behavior of the web services with respect to QoS is difficult to be predicted. It depends on various factors such as availability of the network connection or corresponding application server, the number of simultaneous invocations and so on.
- The client's choice is a result of subjectivity of its own understanding about the desired quality of the offered resources [12].
- The web service quality is affected simultaneously by different QoS properties that often are inconsistent. For example, increasing the availability of a given web service leads to increasing of its cost, which is not reasonable for the clients with limited budget.

B. Current State of the Art

The recently introduced concept of web service quality estimation is based on the probability of the measured quality data and fuzzy sets (FSs) to account for the client preferences [1], [2], [3]. In [15] a web service selection approach based on the weight of client's satisfaction from QoS properties is proposed. Its main drawback is the inability to ensure that the service recommending algorithm is open, fair and trustworthy. Also, only measurable QoS properties are considered. In contrast, a web service selection mechanism proposed in [16] deals with all types of QoS properties expressing those that are not measurable in terms of integer values. The QoS-based selection model described in [17], [18] determines the overall web service quality from a weighted sum of the normalized values of QoS properties. A drawback of the model is that it considers only measurable QoS properties that can be directly monitored. Also, the normalization of the values of QoS properties in the interval of [0,1] leads to losing valuable information. The QoS-aware selection method proposed in [19] performs credibility evaluation of QoS properties that are classified in two categories, i.e. negotiable and nonnegotiable. The values of nonnegotiable QoS properties are obtained from historical records of web service execution and cannot be modified by the provider. The negotiable QoS properties can be changed according to the client's requirements. The web service selection algorithm presented in [20] is based on quantitative QoS prediction method applied to a dynamic environment. In [21] a collaborative filtering based approach is designed. It predicts QoS of unused web services taking into account the similarity in clients experiences. Such similarity is considered also in the service selecting model proposed in [22].

The disadvantages of the approaches presented above can be summarized as follows:

- **Applicability to only measurable QoS properties.** Most of the approaches do not take into account unmeasurable QoS properties.
- **Subjectivity of the performed QoS estimation.** Some approaches are based on the ratings that are specified by clients after web service consumption.

 ISBN: 978-1-61208-432-9

Others use values of QoS properties that are claimed by the web service providers.

- **Applicability to single QoS property.** A significant number of the proposed approaches can be applied in cases when clients are interested in one QoS property in particular. In practice, the web service selection procedure requires consideration of several QoS characteristics.

C. *Research Objectives*

In our previous work [6] we propose an algorithm that enables to compare the quality of several web services with equal functionality according to a single nonfunctional characteristic. It was implemented in a software tool for automated web service selection [14]. However, real practice shows that the service selection usually needs to account for more than one QoS property. An easily applied new method that calculates the level of satisfaction of several jointly estimated quality properties of a particular web service gives a theoretical frame able to assess the strength of the chosen nonfunctional characteristics of a web service [13].

The web service selection approach introduced in this paper is based on the assessed strength of the multiple QoS properties. It calculates the level of satisfaction of several jointly estimated QoS properties for each interested web service using the data collected during the web service invocation. The approach compares the obtained strength level in order to advise the client on the web service with the best quality. It is summarized in an easily implementable algorithm that is proven through a real web service selection scenario.

The rest of the paper is organized as follows. Section II presents the proposed approach for integrated QoS assessment. Section III describes a case study of web service selection as a proof of concept. Section IV concludes the paper and gives directions for future work.

II. Integrated QoS Estimated Method

This section presents a new approach for QoS-enabled selection of web services. First, a theoretical background of the approach is introduced. Next, an integrated QoS assessment for web services is proposed. Finally, a step-by-step procedure for QoS-enabled selection of web services is described.

A. *Theoretical background*

The QoS properties of web services could be divided into groups, namely measurable and unmeasurable [10]. The QoS properties such as response time, availability and throughput are measurable, since they have numerical values. The unmeasurable QoS properties such as standard compliance, authentication method and data encryption cannot be directly measured in terms of numeric values. In contrast, the values of a given measurable QoS property could be easily obtained through monitoring of the web service behavior during operation invocation. They can be treated as values of a random discrete variable known as Probability Mass Function (PMF) [4]. If x is any possible value of a discrete random variable X, the PMF value of x, denoted by $p(x)$, is the probability of the event $\{X=x\}$ consisting of all outcomes that give rise to the value of X equal to x:

$$p(x) = P(\{X=x\}). \qquad (1)$$

The PMF is appropriate for QoS assessment of the web services regarding a single QoS property [11]. Unfortunately, it cannot be applied to the unmeasurable QoS properties. For instance, the QoS metrics that reflect the subjectively experienced quality as usability, efficiency, etc., are in fact the acceptable cumulative effect on client satisfaction of all imperfections affecting the web service [5]. These qualities could be only empirically assessed according to the subjectivity of the client's perception sensed during the web service usage. Usually, such assessment is not exactly defined as it implies some uncertainty. This type of uncertainty can be formalized using a powerful mathematical tool of the theory of fuzzy sets [7].

The concept of fuzzy set allows partial set membership rather than a crisp set membership. The level of belonging is formulated by a membership function, which numerically represents the degree to which a given element belongs to a fuzzy set. Formally, a fuzzy set is defined as follows: a fuzzy set A defined in a universe U is a set of ordered pairs, $A = \{(x, \mu_A(x)), x \in U, \mu_A(x) \in [0,1]\}$, where $\mu_A(x)$ is the degree of membership of the element x in A. Thus, the membership function is seen as a mapping $\mu_A(.)$: $x \rightarrow [0,1]$. As $\mu_A(x)$ approaches 1, the element x increasingly belongs to the fuzzy set A. Commonly, the shape of the membership function is identified as a standard function of triangular, trapezoidal, Gaussian or other type. Usually, it is determined by expert knowledge. However, there are different practical applications, which successfully apply techniques of exploratory data analysis for membership function identification. In such a case, $\mu(.)$ covers the intrinsic process uncertainty that leads to impossibility to find an accurate process description [7]. Since the information for a given QoS property is collected in a data set of measured values then a discrete membership function is applicable to the web service assessment problem. It is interpretable in the sense of probability distribution obtained by (1) [6].

Usually, several quality properties are significant for the web service selection problem. Often they have contradictory effect on the whole service behavior. By improving the quality of one nonfunctional characteristic the quality in the sense of another could decrease. For instance, when web service reliability and safety are increased, its response time could be worsted. Therefore, the joint assessment of several quality properties is essential for the QoS-enabled web service selection.

B. *Integrated QoS estimation*

Let us consider that we have m different web services S_j $j = 1,\ldots,m$ presenting the same functionality. Let us also assume that we have n number of quality properties x_i that determine the QoS properties according to which the web services have to be compared. If each quality property value is presented as a fuzzy set Q^j_i, $j = 1,\ldots, m$, $i = 1,\ldots,n$ as it discussed above, its membership function $\mu_{Q^j_i}(x_i)$ could be represented as PMF according to (1). In such a case, the joint relation of all interested web service QoS properties could be estimated via Cartesian product calculation [13]. The Cartesian product of the fuzzy sets Q^j_i defines a new fuzzy set Q^j of the cross product for the *j*-th service:

$$Q^j = Q^j_1 \times Q^j_2 \times \dots \times Q^j_n. \quad (2)$$

The FS Q^j is a set of all pairs that consists of a tuple of QoS properties' values $x^j = (x^j_1, \dots, x^j_n)$ and its membership degree $\mu_Q^j(x^j)$. That membership degree represents the strength of the relationship of the QoS values of the respective tuple x^j. It is calculated as a minimum of the membership degrees of the constituent membership degree values:

$$\mu_{Q^j}(x^j) = \min_{i=1,n}(\mu_{Q^j_i}(x^j_i)), \text{ for each } j = 1,\dots,m. \quad (3)$$

The degree values obtained in (3) could serve as a QoS assessment and a web service comparison analysis. From a practical point of view, the larger membership degree shows more strength of the QoS. By maximizing the strength, we are able to select a web service, which provides maximal quality. For the QoS properties, whose values have to be minimized in the assessment procedure, the negation of the membership degree:

$$\neg\mu_{Q^j_i}(x^j_i) = 1 - \mu_{Q^j_i}(x^j_i) \quad (4)$$

should be taken in the calculation of (2) and respectively of (3). Thus, at the final stage the largest $\mu_Q^j(x^j)$ value corresponds to the web service that has the best quality and shows the most preferable service behavior:

$$\mu_{Q\max} = \arg\max_{j=1,n}(\mu_{Q^j}(x^j)), \text{ for } j = 1,\dots,m. \quad (5)$$

C. *Integrated QoS selection method*

The theoretical statements presented above can be summarized in a procedure that provides an integrated QoS web services assessment. Let us assume that for a given web service, a number of *n* QoS properties x_i, $i=1,\dots,n$ are of a particular interest. Let the candidate web services, namely those that satisfy functional requirements of the client, form the set *S*, where $S=\{S_1, S_2, \dots, S_j \dots S_m\}$, $j=1,\dots,m$.

The steps of the proposed approach for integrated QoS assessment are as follows:

Step 1: Accumulate data for all interested QoS properties within a chosen time window.

Step 2: Represent each property of each service as a fuzzy set Q^j_i, $j=1,\dots,m$, $i=1,\dots,n$ corresponding to a membership function $\mu_Q{}^j{}_i(x^j{}_i)$.

Step 2 requires calculation of the PMF for each QoS property. In case of available data about the incidence of the QoS values it is processed according to (1) in order to obtain the probability and further, interpret the probabilities values as fuzzy membership degrees. For the properties whose values have to be minimized in the assessment procedure, the negation of the membership degree is performed according to (4).

Step 3: Estimate the Cartesian product of the fuzzy sets Q^j_i, $j=1,\dots,m$, $i=1,\dots,n$ for each web service according to (2) and (3).

Step 4 Apply (5) to select the highest strength that finds the best web service regarding the quality for the considered time window.

III. METHOD VALIDATION

The feasibility of the proposed QoS-enabled approach for web service selection is proved by a sample case study. It covers four web services providing the same functionality of email validation. The web services are compared according to three QoS properties. They are throughput (TP), response time (RT) and number of completed requests (CR). The dataset with QoS values is obtained through load testing of the web services using the LoadUI tool [9]. The TP gives the data transfer rate and is typically measured in bytes per second. The RT gives the time in milliseconds taken to send a request and to receive a response from the web service. The CR provides information about the number of successful processed requests by the web service. Each web service receives 10 requests per second during test case execution. The total number of requests is 1220 and the test case execution time is approximately 20 minutes. This time interval is enough for QoS estimation of the chosen QoS properties, since the behavior of the web services for a longer period of time become repeatable and does not affect the proposed method for QoS estimation. The minimal (*RTmin, TPmin, CRmin*) and maximal values (*RTmax, TPmax, CRmax*) of the QoS properties as well as their maximum of the respective probability *max(P)* for all four web services are presented in Table I, Table II and Table III.

TABLE I. RESPONSE TIME

Web service	Response Time		
	max(P)	***RTmin***	***RTmax***
webserviceex	0.0131	197,7	858.8
cdyne	0.0107	145,82	7308
postcodeanywhere	0.0164	62	383
serviceobjects.net	0.009	324,18	580

TABLE II. THROUGHPUT

Web service	Throughput		
	max(P)	***TPmin***	***TPmax***
webserviceex	0,6959	17379	77775
cdyne	0,7270	0	922240
postcodeanywhere	0,8885	3183	60477
serviceobjects.net	0,5205	209493	302601

TABLE III. COMPLETED REQUESTS

Web service	Completed requests		
	max(P)	***CRmin***	***CRmax***
webserviceex	0,7057	3	20
cdyne	0,7279	0	44
postcodeanywhere	0,8885	1	19
serviceobjects.net	0,5279	9	13

The PMFs calculated for the RT are graphically presented in Figure 1. The maximum of PMFs for all web services is obtained for RT lower than 400 milliseconds. The "cdyne" web service has a big diversity of singly measured values of RT. Its RT varies in a large time interval (see the minimum and maximum value in Table I), but most often is not higher than 200 milliseconds. The X-axis values of the Figure 1 are limited to 2000 and by that increasing the readability and showing better the RT values that are most frequently obtained during web services testing.

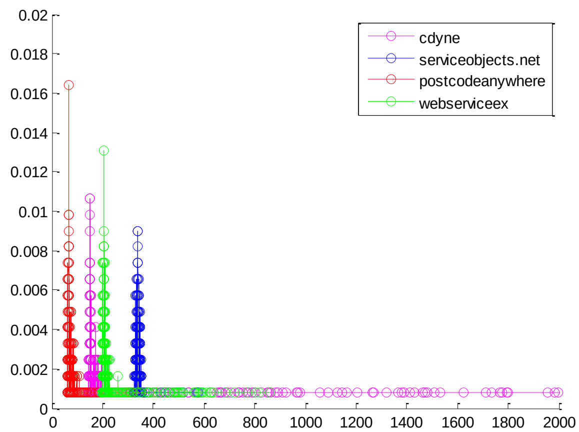

Figure 1. PMFs of Response time.

The PMFs calculated for the TP are graphically presented in Figure 2.

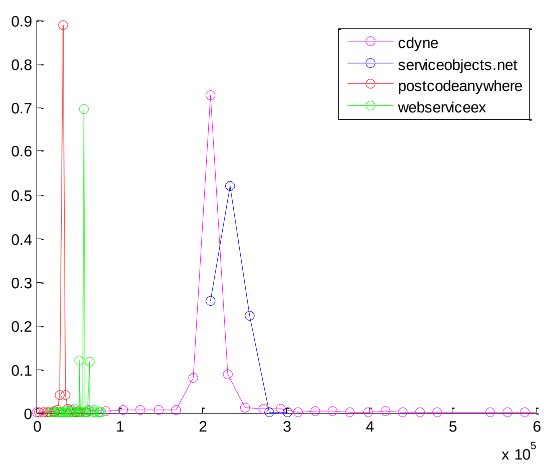

Figure 2. PMFs of Throughput.

The "cdyne" web service has maximum value for the TP 922240 bps (Table II). In order to gain a better readiness the X-axis values of the Figure 2 are limited to 600000. The similar refinement is made regarding the Figure 3 where the X-axis values are limited to 25.

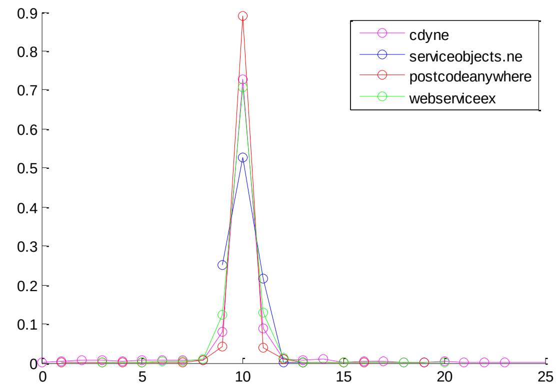

Figure 3. PMFs of Completed requests.

The obtained dataset is used for integrated assessment of the web services' quality. Note that the web services clients expect as higher values as possible for TP and CR. In contrast, regarding the RT the quality is higher when its values are smaller. That is why the PMF of RT is not directly used in calculation procedure, since it needs to be negated according to (4) to obtain the membership degrees of the corresponding fuzzy set Q_{RT}. The PMF of TP and CR are treated as fuzzy sets Q_{TP} and Q_{CR} having the membership degrees that are used directly in the assessment algorithm.

TABLE IV. QOS ASSESMENT

Web service	μ_{Qmax}
webserviceex	0.6959
cdyne	0.7270
postcodeanywhere	0.8885
serviseobjects.net	0.5205

The Cartesian product $Q = Q_{TP} \times Q_{RT} \times Q_{CR}$ of the fuzzy sets related to the QoS properties of interest is calculated according to (2) and (3). The results from the QoS estimation are shown in Table IV. As it was underlined, the membership grade defines the strength of the relationship between the values of QoS properties for each triple. The highest value of 0,8885 is obtained for "postcodeanywhere" web service. It provides the highest quality and is recommended to the client as the best web service for email validation.

IV. CONCLUSION

The proposed approach provides a procedure that assesses the strength of several QoS properties of different web services with equal functionality. It is based on a solid theoretical frame for joint assessment of the QoS properties of interest. The approach calculates the level of satisfaction of the QoS properties using the fuzzy sets description and their cross product in order to find the strength of the relationship between the QoS properties. This is proved through a real web service selection scenario.

Since the proposed approach is based on data obtained through monitoring, it could be realized in a fully automated manner. Further, it uses a theoretical basis that enables to be considered not only measured but also unmeasured QoS properties. The future work includes comparison of the proposed method with other approaches in case of equal web service scenarios and to evaluate the method's effectiveness with larger QoS datasets.

ACKNOWLEDGMENT

The work was supported by the project No 24/2015 sponsored by the Science Fund of Sofia University "Kl. Ohridski", Bulgaria.

REFERENCES

[1] K. F. Abbaci et al., "Selecting and Ranking Business Processes with Preferences: An Approach Based on Fuzzy Sets," Lecture Notes in Computer Science, vol. 7044, Springer-Verlag Berlin Heidelberg, pp. 38-55, 2011.

[2] S. Amdouni et al., "Answering Fuzzy Preference Queries over Data Web Services," Lecture Notes in Computer Science, vol. 7387, Springer-Verlag Berlin Heidelberg, pp. 456-460, 2012.

[3] K. Benouaret et al., "Selecting Skyline Web Services from Uncertain QoS," Proc. Int. Conf. on Services Computing, Honolulu, Hawaii, USA, 2012, pp. 523-530.

[4] J. Devore, Probability and Statistics for Engineering and the Sciences. Brooks/Cole Publisher, Belmont, USA, 2008.

[5] L. Franken, Quality of Service Management: A Model-Based Approach. PhD thesis, Centre for Telematics and Information Technology, 1996.

[6] O. Georgieva and D. Petrova-Antonova, "QoS-aware Web Service Selection Accounting for Uncertain Constraints," Proc. 40th IEEE Euromicro Conference on SEAA, Verona, Italy, 2014, pp. 174-177.

[7] G. Klir and B. Yuan. Fuzzy sets and fuzzy logic: theory and applications, Prentice Hall, USA, 1995.

[8] M. Li et al., "An Adaptive Web Services Selection Method Based on the QoS Prediction Mechanism," Proc. Int. Joint Conf. on Web Intelligence and Intelligent Agent Technology – Workshops, 2009, pp. 395-402.

[9] LoadUI tool. http://www.loadui.org/ (May, 2015).

[10] V. Tran et al., "A new QoS ontology and its QoS-based ranking algorithm for Web services," In Simulation Modelling Practice and Theory, vol. 17, no. 8, pp. 1378-1398, 2009.

[11] D. Petrova-Antonova, "A QoS Aware Approach for Web Service Selection Based on Probability Evaluation," Proc. the IADIS International Conference on Informatics 2011, Rome, Italy, July 2011, pp. 43-50.

[12] P. Xiong and Y. Fan, "QoS-aware Web Service Selection by a Synthetic Weight," Proc. Int. Conf. on Fuzzy Systems and Knowledge Discovery. Haikou, Hainan, China, 2007, pp. 632-637.

[13] O. Georgieva, "Joint assessment of Software Service Quality Properties," Proc. 13th International Conference e-Society, Funchal, Portugal, March 2015, pp.316-315.

[14] D. Petrova-Antonova, N. Hristova and O. Georgieva, "RecSS: automation of QoS-aware web service selection," Proc. the 15th International Conference on Computer Systems and Technologies, Rousse, Bulgaria, June 2014, pp. 256-263, doi 10.1145/2659532.2659632.

[15] S. Li et al., "A Mechanism for Web Service Selection and Recommendation Based on Multi-QoS Constraints," Proc. 6th World Congress on Services. Miami, USA, 2010, pp. 221-228.

[16] D. D'Mello et al., "A QoS Broker Based Architecture for Dynamic Web Service Selection," Proc. Asia Int. Conf. on Modelling & Simulation. Kuala Lumpur, Malaysia, 2008, pp. 101-106.

[17] L. Sha, et al, "A QoS based Web Service Selection Model," Proc. Int. Forum on Inf. Technology and Applications. Chengdu, China, 2009, pp. 353-356.

[18] R.J.R. Raj and T. Sasipraba, "Web service selection based on QoS Constraints," Proc. 2nd IEEE Int. Conf. on Trendz in Information Sciences & Computing, Chennai, 2010, pp. 156-162.

[19] L. Qi, et al., "A QoS-Aware Web Service Selection Method Based on Credibility Evaluation," Proc. Int. Conf. on High Performance Computing and Communications. Melbourne, Australia, 2010, pp. 471-476.

[20] M. Li et al., "An Adaptive Web Services Selection Method Based on the QoS Prediction Mechanism," Proc. Int. Joint Conf. on Web Intelligence and Intelligent Agent Technology – Workshops, 2009, pp. 395-402.

[21] L. Shao et al., "Personalized QoS Prediction for Web Services via Collaborative Filtering," Proc. Int. conf. on Web Services. Salt Lake City, USA, pp. 439-446, 2007.

[22] S. Wang and H. Chen, "A Web Service Selecting Model Based on Measurable QoS Attributes of Client-Side," Proc. Int. Conf. on Computer Science and Software Engineering. Wuhan, China, 2008, pp. 385-389.