The membership function construction in view-based framework

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Abstract. Designing of a service-oriented enterprise system (SoES) is exceedingly complex. One of the most important issues in such a system is modelling of the quality of service (QoS). A lot of different stakeholders often has different understandings of the SoES service quality in definition, specifying and evaluation because QoS is a complex and multi-sided concept. There is a large quantity and variety of interpretations of various service quality concepts and models, but none of them answers us what the general concepts of QoS are. The holistic modelling approach, called a view-based approach that uses viewpoints and perspectives to structure QoS models, is required. Different views are examined here. A view balancing problem must be solved in a view-based enterprise business service quality evaluation framework that uses fuzzy logic concepts with quality categories. The problem of fuzzification of the values of QoS characteristics is examined. The present paper discusses the issues of fuzzification of the values of QoS characteristics using the example of performance characteristic.

Keywords. Service-oriented enterprise systems, quality of service, view-based modelling, fuzzy logic, linguistic variables, membership function

Introduction

Designing of a service-oriented enterprise system is exceedingly complex. One of the most important issues in such a system is modelling of QoS. The different stakeholders often have different understandings of SoES service quality in definition, specifying and evaluation issues, because the QoS is a complex and multi-sided concept. The question “What does the Quality of Service mean?” is not yet finally answered in any context because the Quality of Service concept is ambiguous and difficult to define precisely [1]. According to [2],[3],[4],[5], there is large quantity and variety of interpretations of various service quality concepts and models but none of them answer us what the general concepts of QoS are. The issue of quality evaluation of the overall SoES remains unsolved so far. A holistic modelling approach that uses viewpoints and perspectives to structure QoS models is required [6]. The conceptual view-based framework to describe and relate different viewpoints and perspectives of QoS to each other in web-based SoES was described in [7]. Different views are examined here. A view balancing problem must be solved in a view-based enterprise business service quality evaluation framework that uses fuzzy logic concepts with

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quality categories. The techniques such as fuzzy set theory and fuzzy logic can be successfully applied directly to evaluate the quality, in its vague sense, because it is ambiguous and difficult to define precisely.

The view balancing procedure requires that, in order to be used as input data, the values of QoS characteristics should be fuzzified. The present paper discusses the issues of fuzzification of the values of QoS characteristics, using the example of performance characteristic.

The rest of the paper is organised as follows. Section 1 briefly describes the problem statement and summarises the solution procedure of the view balancing problem in a view-based enterprise business service quality evaluation framework. Section 2 presents the concept of a performance characteristic. Section 3 describes the fuzzification process and examines fuzzification issues related to values of the performance characteristic. Finally, Section 4 concludes the paper.

1. Problem Statement and Solution Procedure

Let us describe the basic notation that we use in modelling a view-based enterprise business service quality evaluation framework [7]:

- X is a set of linguistic variables referred to as EBS quality characteristics;
- $\rho_{eql}^X$ is a labelled equilibrium fuzzy relation on X;
- $\Omega$ is a set of weighted linguistic variables referred to as viewpoints to EBS quality;
- $\rho_{eql}^\Omega$ is a total equilibrium relation on $\Omega$;
- $\Pi$ is a set of weighted linguistic variables describing different aspects of EBS quality (e.g. network aspect, data aspect, etc.) and referred to as perspectives;
- $\Gamma$ is a set of given EBS goals (or qualities);
- $\rho^\psi$ is a fuzzy relation, which relates viewpoints, perspectives and qualities and $\rho^\psi_k, 1 \leq k \leq 6$ is a family of relations produced by projection of $\rho^\psi$ to $\Pi \times \Gamma$;
- $\Phi_1 = \{\rho_{eql}^\psi_k | 1 \leq k \leq 6\}$ is a family of total equilibrium relations (each on corresponding $\rho^\psi_k$);
- $\Phi_2 = \left\{ \Gamma(\Phi_k) \mid 1 \leq k \leq 6, 1 \leq i \leq 8, 1 \leq j \leq n, n \leq N \right\}$ is a family of fuzzy AND trees of EBS quality characteristics, where each tree describes a quality $\gamma_i \in \Gamma$ evaluated from a perspective $\pi_j \in \Pi$ and observed from a viewpoint $\omega_k \in \Omega$;
- Then a tuple $(X, \rho_{eql}^X, \Omega, \rho_{eql}^\Omega, \Pi, \Gamma, \rho^\psi, \Phi_1, \Phi_2, \text{Input}, \text{Output})$, where Input is a set of initial linguistic values of variables from X, describing for each view the bottom level EBS quality characteristics; Output is a final
linguistic value of the balanced view \( v \) on EBS quality and quality characteristics of all levels describing this view, is a view balancing problem.

In the view-based enterprise business service quality evaluation framework, a view balancing problem is solved by the following solution procedure:

- for each viewpoint to set linguistic values of input variables and, using fuzzy relation \( \rho_{eqtb}^X \), to resolve conflicts among these values;
- for each fuzzy tree from the family \( \Phi_2 \) to propagate the defined values forward up to the root of this tree;
- for all viewpoints using the relations from the family \( \Phi_4 \), to resolve conflicts between values of linguistic variables describing qualities, which arise evaluating these qualities from different perspectives;
- for each fuzzy tree from the family \( \Phi_2 \) to propagate the new values of linguistic variables backward to leaf nodes;
- for each viewpoint applying fuzzy graphs union operation to unite trees which describe qualities from different perspectives;
- to infer value of each linguistic variable \( \omega \in \Omega \);
- using relation \( \rho_{eqtb}^H \), to resolve conflicts between values of \( \omega \in \Omega \);
- for all qualities of each viewpoint to propagate new values backward to leaf nodes;
- to choose from \( \Omega \) the variable \( \omega' \) with the greatest weight and to append to the tree associated with this variable missing sub-trees from the trees associated with the other viewpoints;
- to do linguistic approximation of fuzzy values of all output variables.

2. Concept of the performance characteristic

According to the S-Cube Reference Model [8], the performance of service is decomposed into lower level characteristics in the way, presented in Fig. 1.

![Fig. 1. Decomposition of service performance](image)

In the following diagram, we show the defined terms in the general case of a web service scenario, in which a consumer requests the Web service and receives a response.
In Fig. 2, the Consumer is a program. Therefore the performance of service in a computer program is examined at the moment of receipt of the service results, ignoring the working time of the program itself (because, in the case of SoES, this time is similar for all services). The Network encompasses SoES infrastructure. The Provider includes components and Web Service, and the necessary technical equipment and infrastructure. The component is a piece of software that contains the business logic. The Web Service only creates a standardized access to the component interface. The Consumer, Network, and Provider correspond to QoS perspectives. In our case, we examined the services that are not arranged which each other (composition).

Based on Fig. 1 and Fig. 2, we define the quality characteristics that are related to the performance:

\[
\text{Transaction Time} := t_{10} - t_{0} \quad (1)
\]
\[
\text{Response Time} := t_{9} - t_{0} \quad (2)
\]
\[
\text{Throughput}_{\text{Request (Network)}} := \frac{\text{Request data (Mb)}}{t_{5} - t_{0}} \quad (3)
\]
\[
\text{Throughput}_{\text{Response (Network)}} := \frac{\text{Response data (Mb)}}{t_{10} - t_{6}} \quad (4)
\]

\[
\text{Throughput}_{\text{Web Service}} := \frac{\text{Data (Mb)}}{t_{6} - t_{3}} \quad (5)
\]
\[
\text{Latency}_{\text{Network}} := (t_{8} - t_{2}) + (t_{2} - t_{1}) \quad (6)
\]
\[
\text{Latency}_{\text{Provider, Web Service}} := (t_{6} - t_{5}) + (t_{4} - t_{3}) \quad (7)
\]
\[
\text{Execution Time} := t_{4} + t_{5} \quad (8)
\]
\[
\text{Queue Delay Time} := (t_{6} - t_{5}) + (t_{4} - t_{3}) \quad (9)
\]

A view-based framework of QoS in web-based SoES has six viewpoints (metaphysical, cost-based, value-based, pragmatic, provider’s and designer’s) and eight perspectives (presentation, transportation, infrastructure, web service, application, data, socio-economic, and domain). Let us analyze the performance characteristic in a designer’s viewpoint and a web service perspective. At the point of their intersection, the performance characteristic has two measurement values among others: execution
time and throughput. According to S-Cube Reference Model [8], ISO/IEC 25010 [9], the execution time is defined as the time taken by a service to process its sequence of activities and throughput is defined as the amount of data over a time period.

3. Fuzzification process

Fuzzification is the first step in the fuzzy reasoning process [10]. The fuzzification process is primarily based on producing fuzzy information provided by a group of experts, each concept is analyzed into shape membership functions of fixed ranges. Following [11], we define the fuzzification process of input data in 4 steps:

1. Define the linguistic variables and terms;
2. Choose suitable shape of membership function dependend of examined enviroment;
3. Construct the membership functions;
4. Convert crisp input data to fuzzy values using the membership functions (fuzzification).

This paper examines and discuss fuzzification process without the issues of fuzzification of crisp input data to fuzzy values.

3.1 Defining the Linguistic Variables and Terms

The first step of fuzzification process is to define the linguistic inputs variables. Each linguistic variable is divided into set of linguistic terms. For instance, if execution time is interpreted as linguistic variable ($L_{et}$), to qualify this variable, terms such as high, ordinary, and low are used in a QoS context.

Let us suppose that execution time variable $L_{et}$ and throughput variable $L_{thr}$ with common set of linguistic terms is described following:

$$L_{et} = \{high, ordinary, low\} \quad (10)$$

$$L_{thr} = \{high, ordinary, low\} \quad (11)$$

3.2 Choosing of Shape of Membership Function

The choosing of the suitable shape of membership function is important step for accurate fuzzy set application. The membership function can be of different shape such as triangular, trapezoidal, bell-shape curves, S-shape curves, Π-shape curve, Gaussian, and sigmoidal [12],[13],[14]. The suitable shape is selected according to review of the data follows general rules that are described in guidelines [15].

Let us choose the triangular membership function for performance characteristics in view-based framework. It is the most appropriate shape because:

1. Most extensively used in fuzzy sets applications;
2. The simplest type of membership functions through the formulas simplicity and efficiency with respect to computability;
3. Very simple to perform the calculation within the fuzzy controller in a piecewise linear function.
3.3 Construct the Membership Functions

The third step in fuzzification process is construction of the membership function. The physical features found are converted into linguistic variables, using the fuzzification process that transforms crisp values into grades of membership function to linguistic terms of fuzzy sets. In fuzzy logic, each natural-language word is described by the membership function \( \mu(x) \), a function that assigns the degree \( \mu(x) \in [0;1] \) to each number \( x \) which satisfies the corresponding property. In other words, a membership function \( \mu(x) \) defines how each point in the domain of values are mapped to a membership value (or degree of membership) between 0 and 1 which quantifies the grade of membership of the element in \( X \) to the fuzzy set \( A \) [16].

In principle, any fuzzy sets are allowed instead of triangular functions. In order to interpret the fuzzy sets as approximate numerical values or fuzzy intervals, unimodal functions are recommended to fuzzy numbers or fuzzy intervals respectively, i.e. the elements from \( F_{I}(R) \) [17],[18]. Frequently, the fuzzy sets are selected in such way that the condition is met,

\[
i \neq j \Rightarrow \sup_{x \in X_i} \{ \min \{ \mu_i^{(1)}(x), \mu_j^{(1)}(x) \} \} \leq 0.5
\]  

(12)

We assume that the provider of web service states the performance data. Further we assume that amount of data of requests and response is normally distributed. The provider ensures the average (\( et_{\text{avg}} \)) and maximum (\( et_{\text{max}} \)) execution time for the middle data volume.

Now we can build membership functions of a low quality, ordinary quality, and high quality:

\[
\mu_{\text{ordinary}}(x) = \begin{cases} \frac{1}{et_{\text{avg}}} x & x \in [0; et_{\text{avg}}) \\ \frac{1}{et_{\text{avg}}-et_{\text{max}}} x - \frac{et_{\text{max}}}{et_{\text{avg}}-et_{\text{max}}} & x \in [et_{\text{avg}}; et_{\text{max}}] \\ 0 & x \in (et_{\text{max}}; +\infty) \end{cases}
\]  

(13)

\[
\mu_{\text{high}}(x) = \begin{cases} \frac{1}{et_{\text{avg}}} x & x = 0 \\ 1 - \frac{1}{et_{\text{avg}}} x & x \in (0; et_{\text{avg}}] \\ 0 & x \in (et_{\text{avg}}; +\infty) \end{cases}
\]  

(14)

\[
\mu_{\text{low}}(x) = \begin{cases} \frac{0}{et_{\text{max}}-et_{\text{avg}}} x - \frac{et_{\text{avg}}}{et_{\text{max}}-et_{\text{avg}}} & x \in [0; et_{\text{avg}}) \\ \frac{1}{et_{\text{max}}-et_{\text{avg}}} x & x \in [et_{\text{avg}}; et_{\text{max}}] \\ 1 & x = (et_{\text{max}}; +\infty) \end{cases}
\]  

(15)
We choose such membership functions for the following reasons. The execution time is sufficient, if it takes the average time stated by the provider. If it is faster, it is also sufficient. All the values higher than the stated maximum execution time are not sufficient. All the values higher than the maximum time are definitely slow, if the execution time is higher than the average time it is “little bit” slow.

Membership functions for other subcharacteristics of the performance can be defined using the same approach.

The next step in the fuzzification process is to convert crisp input data into fuzzy values using the membership functions. The paper does not consider this issue.

4. Conclusions

The view integration and reconciliation methodology can also be successfully applied to solve a view balancing problem in service quality requirements formulation context. Quality is vague concept and fuzzy set theory, and fuzzy logic techniques can be applied directly to evaluate the quality goals.

This paper has shown the construction of membership function of the values of the QoS performance characteristic using fuzzy logic concepts with quality categories. In this paper we have made two basic assumptions: the measurable performance values are normally distributed and simple linear membership functions are used. To handle scenarios, in which these assumptions do not fit, is much more complex and part of future research.

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