Optimal Web Service Selection Model using Fuzzy Extended AHP and Weighted Sum Method

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ABSTRACT: *Different services have different values for their different properties (functional and non-functional). Moreover, consumers have different preferences for these properties. Since these preferences may be incomplete/vague/imprecise, this inevitably can in turn cause selection of a non-optimal service for the consumer which may not have the desired value for these properties for the consumer. Therefore optimal web service selection based on the consumer's preferences is a challenging task. In this paper, a new service selection model is proposed which considers consumer preferences for different service properties as well as the actual values of its properties. Services are evaluated and priority weights are computed separately for functional and non-functional properties using modified Fuzzy Extended Analytic Hierarchy Process (FEAHP) and Weighted Sum Method (WSM) respectively. Real time data is used to conduct experiments.*

Subject Categories and Descriptors

[H.3.5 Online Information Services]; Web-based services: [I.2.3 Deduction and Theorem Proving]; Fuzzy, and probabilistic reasoning

General Terms:

Fuzzy Process; Web Services

Keywords: Web Service, Functional Property, Non-functional Property, Fuzzy Extended AHP, Weighted Sum Method

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1. Introduction

Service Oriented Architecture (SOA) is becoming a widespread solution for realizing distributed applications such as e-business and enterprise systems via web services. Web services in SOA are autonomous entities which are published, located, and accessed through messages encoded as per the XML-based standards (Erl, 2005; Erl, 2008;). Service providers describe their services using Web Service Description Language (WSDL) and publish them in a central repository. Service consumers invoke these services (Erl, 2015).

A service has certain functional aspects and certain non-functional aspects. The functional properties of a service are derived from its functional aspects which are the overall number of functionalities (operations) that it provides and how many times it has been invoked by the consumers. These properties are based on its WSDL document. The non-functional properties capture the non-functional aspects (QoS) of services (Choi & Kim, 2008; Gebhart, 2013; Senivongse et al., 2010). There are various non-functional properties (QoS) of services such as throughput, latency, response time, reliability, availability etc (Balfagih, 2009; Kim & Lee, 2005; Kim et al., 2010). A consumer has certain preferences for each of these properties for a service. Therefore, in this paper, following aspects are collectively considered while proposing the service selection model.

1) A service has certain values for each of its property (functional and non-functional).

2) A consumer has certain preferences for each of these properties.

First, consider functional properties of services. A consumer search for a service having functionality for e.g., 'weather prediction'. There may be many services which provides this functionality but varies in the spectrum of overall provided functionalities. These services are known as alternate services. For example, some service predicts weather 'by city' and 'for a particular date', some service predicts weather 'by city and for a particular whole week and some service predicts weather 'by city' and 'gives related warnings'. Among these alternate web services, there are some which offer a wide spectrum of functionalities and some offers less. Furthermore, within these, there are some services which are frequently used and some are not. In this way, with respect to the values of these functional properties, services have relative priorities over each other. A consumer may have different preferences for both of these functional properties i.e. there may be a consumer who does not want bulky service but most frequently used service.

Now, consider non-functional properties of services. A consumer requests for a service which fulfills the desired non-functional properties. Some services have low values for some property and some have high. In this way, for non-functional properties also each service has a relative priority over another. Essentially, consumers have incomplete and imprecise preferences for different non-functional properties and therefore, it becomes hard to quantify these preferences especially the importance of preferences. Such vague preferences may lead to selection of a non-optimal service as it may lead to selection of a service with non-desired values for its different properties. Therefore, it becomes inevitable to consider both actual values of properties and consumer's preferences.

From the aforementioned, optimal service selection is a complex decision problem. Hence in this context, fuzzy logic is used to provide a solution for this multi-criteria selection problem. Fuzzy set theory is used in handling the approximation and uncertainty in making decisions which bears a resemblance to human reasoning (Dijkman et al., 1983; Zadeh, 1997; Zimmermann, 2011). In the existing research for the web service selection, fuzzy approaches have been used (Chao et al. 2005; Huang et al., 2005; Lin et al., 2005; Tran & Tsuji, 2008; Wang et al., 2006; Xiong & Fan, 2007). Existing approaches lack the study of consumer's preferences which are uncertain for properties with respect to other properties. This uncertainty in turn can impact the determination of ranks of services for the consumer, for example, when a consumer is not certain that whether a property A is of more priority for her/him than property B. To overcome the limitations of the existing research, the proposed model

uses fuzzy extended AHP. This method has various processes such as decomposition, pairwise comparisons, priority weights generation and ranking processes (Chang, 1996; Chen et al., 1982; Saaty, 1980). It handles multiple criteria with relative ease and is easier to understand as it does not involve cumbersome arithmetic. In the method, the expert's knowledge for the preferences is used in the selection process, but in this paper, this is replaced by the priority of the services based on their actual values for each property.

There are research works which have integrated both functional and non-functional requirements in a software development process using Fuzzy AHP methodology (Dabbagh & Lee, 2014; Dabbagh et al., 2016; Khan, 2016; Mansoor et al., 2015). In this paper, the proposed model also considers both functional as well as non-functional properties of services while selecting a service for the consumer. In the model, a consumer while making a service request provides the required functionality, fuzzy preferences (such as weakly more important, strongly more important, equally important etc.) for non-functional properties and linguistic preferences (such low, medium etc.) for the functional properties.

The research contributions of the paper for service selection are as follows:

1) Fuzzy priority weights computation of services based on their actual values of the functional properties and consumer's preferences for these properties. Weighted Sum Method is used to compute priority weights of the service for both of these aspects.

2) Fuzzy priority weights computation of services based on their actual values of non-functional properties and consumer's preferences for these properties: Fuzzy extended AHP is used for both of these aspects.

3) Functional & Non-functional aware fuzzy ranking of services: Aggregation of both functional and non-functional priority weights is done to provide the optimal service for the consumer.

The research intends not to miss (due to the vague preferences) an optimal service which may be best suited service for the consumer. In this way, the proposed model assists in service selection to bring essential benefits for the service consumers.

The remainder of the paper is organized as follows. The basic terminologies are discussed in Section 2. The proposed model is introduced in Section 3. Experiments and Results are explained in Section 4 to illustrate the proposed model. Section 5 examines the sensitivity analysis of the proposed model. Finally, the paper is concluded in Section 6.

2. Definitions

Definition 1: (Pedrycz & Gomide, 1998) A fuzzy set F is

defined as a set of ordered pairs in the form $\{(p, \mu_F \sim p: x \in \cup, \mu_F \sim p \in [0,1])\}$. The value $\mu_F \sim p$ is known as the membership degree of p in set F . It is the degree to which the set member p possess the characteristic property of F . This means that the membership degree of p in F increase as the value of $\mu_F \sim p$ is nearer to 1.

Definition 2: (Kauffman & Gupta, 1985) A fuzzy number is expressed as a fuzzy set which defines a fuzzy interval containing real numbers ($\mathbb{R}$) from the interval $[0,1]$. A fuzzy number $F \sim$ has functional value $\mu_F \sim p = 1$ at precisely single element from a given set of elements. Fuzzy numbers are suitable for modeling uncertainty in different kinds of applications.

Definition 3: (Fuller, 1997) A Triangular Fuzzy Number (TFN) is a special case of fuzzy number which is defined as $F \sim = (f_1, f_2, f_3)$. It has membership function $\mu_F \sim$

$$\mu_F \sim p = \begin{cases} 0 & \text{if } p \leq f_1 \\ \frac{p-f_1}{f_2-f_1} & \text{if } f_1 \leq p \leq f_2 \\ \frac{f_3-p}{f_3-f_2} & \text{if } f_2 \leq p \leq f_3 \\ 0 & \text{if } p > f_3 \end{cases} \quad (1)$$

where f_1, f_2, f_3 are given numbers. The membership function of a triangular fuzzy number is represented graphically as a triangle in which $[f_1, f_3]$ forms base of the triangle and the

point $(f_2, 1)$ as the vertex. Therefore, the real numbers f_1, f_2, f_3 together defines the triangular fuzzy number and is denoted as (f_1, f_2, f_3) .

Definition 4: (Fishburn, 1967) Weighted Sum Method (WSM) is a multi-criteria decision making method to evaluate a number of alternatives for different decision criteria. The weighted sum of A_i alternative is represented as

$$\sum_{j=1}^n w_j a_{ij} \quad \text{for } i = 1, 2, \dots, m \quad (2)$$

where w_j denotes the relative weight of importance of the criterion C_j and a_{ij} is the performance value of alternative A_i . Each alternative is evaluated in terms of criterion C_j .

Definition 5: (Fan, M & Zhang, 2002) A Fuzzy comparison matrix aims to express the consumer's preferences in the form of a pairwise comparison matrix resulting among different alternatives. The members of the matrix are triangular fuzzy numbers. The matrix allows the decision makers to give fuzzy preferences instead of precise preferences for a pairwise comparison among various alternatives. It is represented as

$$F \sim = \begin{matrix} & A_1 & A_2 \\ A_1 & [f_1^{11}, f_2^{11}, f_3^{11}] & [f_1^{12}, f_2^{12}, f_3^{12}] \\ A_2 & [f_1^{21}, f_2^{21}, f_3^{21}] & [f_1^{22}, f_2^{22}, f_3^{22}] \end{matrix}$$

where $f_{ij} \sim = (f_1^{ij}, f_2^{ij}, f_3^{ij})$ is the triangular fuzzy number representing the fuzzy relative consumer's preference for alternatives A_i and A_j .

Figure 1. Proposed Model

3. Proposed Model

A service consumer sends the request for a required functionality along with preferences for the functional and non-functional properties via a user interface. Services are stored in the service repository as per their functionality (basic). For example, weather prediction and zipcode search services are stored in separate groups. However, there may be more than one service which predicts weather or finds zipcode with different functional and non-functional properties. WSDL documents of the services are stored along with their functional and non-functional properties in the service repository. The service repository is searched for the required functionality. The services which match the required functionality are termed as alternate services. The values of non-functional properties of each alternate service relative to each other are converted to triangular fuzzy numbers. The Fuzzy Extended AHP (FEAHP Module) uses these numbers and the consumers preferences for non-functional properties and computes their corresponding priority weights. The output from this module is all the alternate services with their priority weights with respect to the non-functional properties. The linguistic consumer's preferences of functional properties are converted to crisp fuzzy values. These are used together with the values of functional properties of each alternate service in the Weighted Sum Model (WS Module). The output from this module is all the alternate services with their priority weights with respect to the functional properties. Finally, priority weights for both properties are aggregated to select the optimal service for the service consumer. The proposed model is

depicted in Figure 1.

Fuzzy AHP methods are systematic approaches to the alternative selection by using the concepts of hierarchical structure analysis and fuzzy set theory. The hierarchical structure for the goal to select optimal service has different levels which include alternate services and the properties (Functional and Non- functional) are shown in Figure 2.

The non-functional properties of the alternate services are handled using Fuzzy extended AHP (FEAHP) method while functional properties are handled using Weighted Sum Method (WSM).

a) First, non-functional properties are discussed which uses Fuzzy set theory to help the decision makers to make interval judgments than fixed value judgments which they usually find more confident to give. The linguistic consumers preferences of each non-functional property are converted into triangular fuzzy numbers. This will provide the importance of each non-functional property. These are represented in triangular fuzzy scale as presented in Table 1. After converting preferences and actual values of non- functional properties to TFNs, a fuzzy comparison matrix M is constructed where $m_{ij} = a_{ij}, b_{ij}, c_{ij}$ is the relative importance of i th non-functional property over j th non-functional property in pair wise comparison and a_{ij}, b_{ij}, c_{ij} are the least bound, middle bound and highest bound values respectively. Fuzzy extended AHP (FEAHP) method is performed on these fuzzy comparison matrices (Chang, 1996; Pal, 2007; Saaty, 1980).

Figure 2. The hierarchical structure

Linguistic Scale	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal Scale
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Table 1. Triangular Fuzzy Scale for Consumer's Preferences for Non-Functional Properties

Relative Difference Scale (Pd)	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal Scale
< 0 %	(1/2, 1, 3/2)	(2/3, 1, 2)
25%> PD > 0%	(1, 3/2, 2)	(1/2, 2/3, 1)
50%> PD > 25%	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
75%> PD > 50%	(2, 5/2, 3)	(1/3, 2/5, 1/2)
>75%	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Table 2. Triangular Fuzzy Scale for actual values of Non-Functional Properties

Consumer Preferences	Priority Weights
Low	.1
Medium	.3
High	.6

Table 3. Priority weights for the Functional Properties

To decide on the relative importance of each non-functional property for their actual values, the relative difference percentage between values of each alternate service is computed. This is expressed as a ratio so as to maintain the consistency ratio used in the FEHP method.

$$\text{Relative Difference Percentage } (v_1, v_2) = \frac{|\Delta|}{f(v_1, v_2)} \quad (4)$$

$$\text{where } f(v_1, v_2) = \frac{v_1 + v_2}{2}$$

For example, if for non-functional property (Response Time), an alternate service has a normalized value .5 and another alternate service has a normalized value .7 then the Relative Difference Percentage is 33%. The Percentage Difference scale is used to convert the percentage difference to triangular fuzzy numbers. These are shown in Table 2.

FEAP method considers the extent to which an object

can satisfy the goal. In this method the extent is quantified using triangular fuzzy number. The normalized weight vectors of all the fuzzy comparison matrices are aggregated to obtain priority weights of the alternate services as per their non-functional properties.

b) Now, functional properties are discussed. In this paper, Weighted Sum Method (WSM) is used to deal these properties. The consumer's preferences and the actual values of each functional property are considered to compute priority weights of the alternate services. The consumer's preferences for each property provided by the user interface are assigned priority weights as per their relative importance. The priority weights are so given that the total sum is 1. These are listed in Table 3.

Priority weights of each service are computed using above weights.

c) Now when priority weights of each alternate service are computed for both functional and non-functional properties,

both of these are aggregated. The service with the highest priority weight is the optimal service for the consumer.

4. Experiments and Analysis

This section describes the system development environment, performed experiments and results.

4.1 System Development

This system is built on an Intel(R) Core(TM) i7-3770 CPU@3.40GHz processor, 64-bit operating system and 6 GB Memory. The User Interface is built in MATLAB R2015a (64-Bit). The service functionality is searched via a WSDL Parser which is developed using Eclipse 4.6.0 (Neon). SQL Server is used to store and manage all the information about services such as their description, non-functional properties and functional properties. Figure 3 shows the User Interface which takes the consumer inputs for the preferences for each property.

4.2 Experiments

To perform the experiments, real time data (Al-Masri, 2007) is used which comprises of 2307 services. It consists of QoS data for each service with nine QoS parameters: Response Time, Availability, Throughput, Successability, Reliability, Compliance, Best Practices, Latency and

Documentation. These QoS parameters are used for the non-functional properties in the proposed model. For the functional properties, the number of overall functionalities is extracted from the WSDL files of the services using WSDL4j Parser and number of invocations of each service is generated randomly using Java code in Eclipse.

4.3 Results

The model is demonstrated for a service request for the required functionality forecastWeather along with preferences for different properties by the service consumer. There are four alternate services present in the service repository which match this required functionality: ndfdXML (outputs Minimum and Maximum Temperature, wind speed, weather warnings, rain, snow prediction etc), globalweather (outputs Temperature and Humidity in the weather report), usweather (provides Temperature in Http and in SOAP) and WeatherStation Service (provides Temperature only). Following the model methodology, following tables are generated.

Firstly, the Fuzzy Comparison Matrices are constructed for the Non-Functional properties. Table 4 shows the Fuzzy Comparison Matrix for the consumer preferences for the Non-Functional properties.

Optimal Web Service Selection based on the Proposed Model

Please select the Required Functionality

ForecastWeather

InformationOfAccount

SearchServiceAmazon

ZipCodeFinder

Please provide your preferences for Functional Properties

Number of Offered Functionalities

Number of Invocations

Medium

High

Please provide your preferences for Non-Functional Properties

Response Time

Availability

Throughput

Successability

Throughput

Successability

Reliability

Compliance

Equally important

Weakly more important

< >

Select Optimal Service

Figure 3. User Interface of the Proposed Model

QoS Parameters	Response Time	Availability	Throughput	Successability	Reliability	Compliance	Best Practices	Latency	Documentation
Response Time	[1 1 1]	[3/2 2 5/2]	[2 5/2 3]	[1/2 1 3/2]	[1 3/2 2]	[5/2 3 7/2]	[5/2 3 7/2]	[1 3/2 2]	[1 3/2 2]
Availability	[2/5 1/2 2/3]	[1 1 1]	[1/2 1 3/2]	[1 3/2 2]	[1 3/2 2]	[1 3/2 2]	[5/2 3 7/2]	[2 5/2 3]	[1 3/2 2]
Throughput	[1/3 2/5 1/2]	[2/3 1 2]	[1 1 1]	[1 3/2 2]	[1 3/2 2]	[1/2 1 3/2]	[1/2 1 3/2]	[1 3/2 2]	[3/2 2 5/2]
Successability	[2/3 1 2]	[1/2 2/3 1]	[1/2 2/3 1]	[1 1 1]	[5/2 3 7/2]	[3/2 2 5/2]	[5/2 3 7/2]	[3/2 2 5/2]	[5/2 3 7/2]
Reliability	[1/2 2/3 1]	[1/2 2/3 1]	[1/2 2/3 1]	[2/7 1/3 2/5]	[1 1 1]	[3/2 2 5/2]	[5/2 3 7/2]	[3/2 2 5/2]	[5/2 3 7/2]
Compliance	[2/7 1/3 2/5]	[1/2 2/3 1]	[2/3 1 2]	[2/5 1/2 2/3]	[2/5 1/2 2/3]	[1 1 1]	[3/2 2 5/2]	[1 3/2 2]	[3/2 2 5/2]
Best Practices	[2/7 1/3 2/5]	[2/7 1/3 2/5]	[2/3 1 2]	[2/7 1/3 2/5]	[2/7 1/3 2/5]	[2/5 1/2 2/3]	[1 1 1]	[3/2 2 5/2]	[2 5/2 3]
Latency	[1/2 2/3 1]	[1/3 2/5 1/2]	[1/2 2/3 1]	[2/5 1/2 2/3]	[2/5 1/2 2/3]	[1/2 2/3 1]	[2/5 1/2 2/3]	[1 1 1]	[5/2 3 7/2]
Documentation	[1/2 2/3 1]	[1/2 2/3 1]	[2/5 1/2 2/3]	[2/7 1/3 2/5]	[2/7 1/3 2/5]	[2/5 1/2 2/3]	[1/3 2/5 1/2]	[2/7 1/3 2/5]	[1 1 1]

Table 4. Fuzzy Comparison Matrix for Consumer Preferences for the Non-Functional Properties

Then, the fuzzy comparison matrices are constructed for the actual values of each non-functional property by using

Relative Difference Percentage Computation mentioned in Eq. (4). These are shown in the tables from Table 5-13.

Response Time	ndfdXML	globalweather	usweather	WeatherStationService
ndfdXML	(1, 1, 1)	(5/2, 3, 7/2)	(1, 3/2, 2)	(5/2, 3, 7/2)
globalweather	(2/7, 1/3, 2/5)	(1, 1, 1)	(1/2, 1, 3/2)	(1, 3/2, 2)
usweather	(1/2, 2/3, 1)	(2/3, 1, 2)	(1, 1, 1)	(5/2, 3, 7/2)
WeatherStationService	(2/7, 1/3, 2/5)	(2/3, 1, 2)	(2/7, 1/3, 2/5)	(1, 1, 1)

Table 5. Fuzzy Comparison Matrix for Response Time Non-Functional Property

Availability	ndfdX ML	globalweather	usweat her	WeatherStationS ervice
ndfdXML	(1,1,1)	(1/2, 1, 3/2)	(1/2,1,3/2)	(1/2, 1, 3/2)
globalweather	(2/3,1,2)	(1, 1, 1)	(1/2,1 3/2)	(1/2, 1, 3/2)
usweather	(2/3,1,2)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)
WeatherStationService	(2/3,1,2)	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)

Table 6. Fuzzy Comparison Matrix for Availability Non-Functional Property

Throughput	ndfdXML	globalweather	usweather	WeatherStationService
ndfdXML	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
globalweather	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
usweather	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)
WeatherStationService	(2/3, 1, 2)	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)

Table 7. Fuzzy Comparison Matrix for Throughput Non-Functional Property

Successability	ndfdXML	globalweather	usweather	WeatherStationService
ndfdXML	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
globalweather	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
usweather	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)
WeatherStationService	(2/3, 1, 2)	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)

Table 8. Fuzzy Comparison Matrix for Successability Non-Functional Property

Reliability	ndfdXML	globalweather	usweather	WeatherStationService
ndfdXML	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
globalweather	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
usweather	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)
WeatherStationService	(2/3, 1, 2)	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)

Table 9. Fuzzy Comparison Matrix for Reliability Non-Functional Property

Compliance	ndfdXML	globalweather	usweather	WeatherStationService
ndfdXML	(1, 1, 1)	(1, 3/2, 2)	(1, 3/2, 2)	(1/2, 1, 3/2)
globalweather	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
usweather	(1/2, 2/3, 1)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)
WeatherStationService	(2/3, 1, 2)	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)

Table 10. Fuzzy Comparison Matrix for Compliance Non-Functional Property

Best Practices	ndfdXML	globalweather	usweather	WeatherStationService
ndfdXML	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 2)	(1/2, 1, 3/2)
globalweather	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 2)	(1, 3/2, 2)
usweather	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)	(1, 3/2, 2)
WeatherStationService	(2/3, 1, 2)	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1, 1, 1)

Table 11. Fuzzy Comparison Matrix for Best Practices Non-Functional Property

Latency	ndfdXML	globalweather	usweather	WeatherStationService
ndfdXML	(1, 1, 1)	(1/2, 1, 3/2)	(5/2, 3, 7/2)	(1/2, 1, 3/2)
globalweather	(2/3, 1, 2)	(1, 1, 1)	(5/2, 3, 7/2)	(5/2, 3, 7/2)
usweather	(2/7, 1/3, 2/5)	(2/7, 1/3, 2/5)	(1, 1, 1)	(1/2, 1, 3/2)
WeatherStationService	(2/3, 1, 2)	(2/7, 1/3, 2/5)	(2/3, 1, 2)	(1, 1, 1)

Table 12. Fuzzy Comparison Matrix for Latency Non-Functional Property

Documentation	ndfdXML	globalweather	usweather	WeatherStationService
ndfdXML	(1, 1, 1)	(1, 3/2, 2)	(1, 3/2, 2)	(5/2, 3, 7/2)
globalweather	(1/2, 2/3, 1)	(1, 1, 1)	(1, 3/2, 2)	(5/2, 3, 7/2)
usweather	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1, 1, 1)	(5/2, 3, 7/2)
WeatherStationService	(2/7, 1/3, 2/5)	(2/7, 1/3, 2/5)	(2/7, 1/3, 2/5)	(1, 1, 1)

Table 13. Fuzzy Comparison Matrix for Documentation Non-Functional Property

	Response Time	Avail ability	Through put	Success ability	Reliability	Com pliance	Best Practices	Latency	Docu- mentation	Service Priority Weight
Alternate services	0.207	0.1669	0.1238	0.1987	0.1546	0.0932	0.0611	0.0464	-0.0517	
ndfdXML	0.593	0.25	0.267	0.25	0.25	0.28	0.263	0.31	0.52	0.3165
global weather	0.067	0.25	0.230	0.25	0.25	0.22	0.263	-0.28	0.44	0.1734
usweather	0.340	0.25	0.250	0.25	0.25	0.23	0.263	0.59	0.349	0.2785
Weather Station Service	-0.001	0.25	0.251	0.25	0.25	0.25	0.2108	0.377	-0.317	0.2314

Table 14. Priority Weights of Alternate services for Non-Functional Properties

The normalized weight vectors of the above matrices are computed after applying FEAHM method steps mentioned in Section 4. The normalized weight vectors for the

Table 4 are [0.2070 0.1669 0.1238 0.1987 0.1546 0.0932 0.0611 0.0464 -0.0517]

Table 5 are [0.5933 0.0679 0.3407 -0.0019]

Table 6 are [0.2500 0.2500 0.2500 0.2500]

Table 7 are [0.2675 0.2302 0.2504 0.2519]

Table 8 are [0.2500 0.2500 0.2500 0.2500]

Table 9 are [0.2500 0.2500 0.2500 0.2500]

Table 10 are [0.2893 0.2244 0.2312 0.2550]

Table 11 are [0.2631 0.2631 0.2631 0.2108]

Table 12 are [0.3171 -0.2854 0.5909 0.3773]

Table 13 are [0.5254 0.4434 0.3492 -0.3179]

Now, above calculate weight vectors are aggregated to compute Priority Weight of each alternate service for non-functional properties. Table 14 shows resultant priority weights.

Now, service priority weights are computed using WSM method for the functional properties. The results are shown in Table 15.

Functional Properties Preferences	No of offered functionalities	No of invocations	Service Priority Weight
Weights	0.4	0.6	
Alternate services			
usweather	0.136363636	0.142857143	0.14025974
globalweather	0.272727273	0.142857143	0.194805195
ndfdXMLweather	0.545454545	0.285714286	0.38961039
WeatherStationService	0.045454545	0.428571429	0.275324675

Table 15. Priority Weights of Alternate services for Functional Properties

Alternate services	ndfdXML	globalweather	usweather	WeatherStationService
Integrated priority weights	0.623061536	0.326673963	0.390899452	0.459352028

Table 16. Integrated priority weights of Alternate services

Now, both priority weights (functional and non-functional properties) are integrated to get the aggregated priority weights of the all the alternate services. The results are shown in Table 16.

weight in Table 16. The service **ndfdXML** has the highest priority weight among all.

5. Sensitivity Analysis

The optimal service is the one with the highest priority

Sensitivity analysis is performed for the proposed model

Consumer's preferences for Non-Functional Properties									Priority Weights for Alternate services			
Response Time	Availability	Throughput	Successability	Reliability	Compliance	Best Practices	Latency	Documentation	ndfd XML	global weather	usweather	WeatherStationService
0.207	0.1669	0.1238	0.1987	0.1546	0.0932	0.0611	0.0464	-0.0517	0.316568	0.173427	0.278562	0.23143
0.2	0.161	0.13	0.181	0.1628	0.0966	0.077	0.045	-0.0534	0.314053	0.175121	0.277428	0.233386
0.195	0.153	0.1365	0.179	0.176	0.0845	0.087	0.056	-0.067	0.309099	0.167824	0.279736	0.243329
0.19	0.188	0.1382	0.18	0.169	0.0778	0.078	0.067	-0.088	0.301985	0.164561	0.27422	0.246423
0.185	0.19	0.156	0.179	0.18	0.0666	0.0654	0.045	-0.067	0.304282	0.167824	0.279736	0.263497
0.18	0.161	0.144	0.211	0.149	0.088	0.056	0.056	-0.045	0.309871	0.166234	0.27322	0.262886
0.175	0.177	0.134	0.205	0.169	0.099	0.069	0.049	-0.077	0.299299	0.171162	0.29453	0.257443
0.17	0.28	0.0548	0.1912	0.159	0.089	0.045	0.056	-0.045	0.304772	0.165633	0.28004	0.244456
0.165	0.199	0.136	0.189	0.169	0.078	0.077	0.053	-0.066	0.298479	0.182366	0.27646	0.243766
0.16	0.178	0.133	0.158	0.166	0.1	0.108	0.077	-0.08	0.295735	0.174665	0.27965	0.25767
0.155	0.189	0.132	0.199	0.165	0.086	0.078	0.051	-0.055	0.298198	0.178866	0.279736	0.26456

Table 17. Sensitivity Analysis of the Proposed Model

to check the impact of fuzziness on the solution provided by the proposed model. The level of imprecision in the consumer's preferences for the non-functional properties is way more than for the functional properties. Therefore, the impact of this fuzziness in consumer's preferences on the optimal service selection is analyzed for non-functional properties. Table 17 contains the priority weights of alternate services for different priority weights of all the non-functional properties. It is shown from the priority weights for consumer's preferences of non-functional properties in Table 4 that Response Time is the most preferred non-functional property. Thus, this non-functional property is chosen to study the impact of fuzziness in consumer's preferences on the service selection. The fuzziness in the preferences for Response Time is varied at constant intervals. Consumer's preferences of other non-functional properties also vary such that their sum is 1 to maintain the consistency.

Table 17 shows that service **ndfdXML** is selected even when fuzziness vary in the consumer's preferences. This shows that the proposed model has handled the fuzziness in the consumer's preferences efficiently.

To summarize, contribution of the paper are as follows.

- a) Weighted Sum Method is used to prioritize alternate services as per their functional properties and on the basis of consumer's preferences. This would result in functional aware fuzzy ranking of alternate services for the consumer.
- b) Fuzzy extended AHP method is used to prioritize alternate services as per their non-functional properties and on the basis of consumer's preferences. This would result in non-functional aware fuzzy ranking of alternate services.
- c) The fuzzy ranking of each alternate service based on functional as well as on non-functional properties is finally combined to select the optimal service which best suits the requirements of the consumer.

6. Conclusion

There are different services which provide same basic functionality but have different values for their functional and non-functional properties. When a service is requested by the service consumer, the preferences may be incomplete/vague/imprecise for these properties. Therefore with regards to these concerns, to select a service which is optimal for the consumer becomes difficult. The proposed model handled both the concerns in its service selection process. Modified Fuzzy Extended Analytic Hierarchy Process (FEAHP) and Weighted Sum Method (WSM) are used in the proposed model. Real time data of web services is used to demonstrate the model. A sensitivity analysis is done for determining the impact of fuzziness for the importance levels of the preferences on the service selection. The model is found to be effective to select the optimal service for the consumers preferences.

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