A Utility Model for Negotiation between Semantic Web Services

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Abstract: - Using the utility-theory for the decision-making process during the negotiation between semantic web services is an appealing one. This paper proposes a computational model for the calculation of utilities of the negotiating semantic web services. The proposed model uses multiple attribute in the utility function and uses the basic values of these attributes such as values for offered price, quality and others. The model is based on a novel understanding that a service requester should remain indifferent to the changes in price or other such values if the corresponding quality has also been changed accordingly. A prototype system has been implemented in support of the proposed model. The work has been evaluated and the betterment has been reported.

Key-Words: - utility, semantic web, semantic web services, negotiation, computation

1 Introduction

Utility theory is the appealing form of representing inputs to decision-making under uncertainty for automated systems because it can readily be mapped onto numerical optimization-based approaches [1]. So, this approach can be well suited for the negotiation between semantic web services (SWSs), as the ultimate aim of the SWSs is to provide automatic support for discovery, composition, and execution of web services by means their explicit semantic annotation [2]. In the semantic web based systems, usually single SWS can not satisfy the user's request and it needs to take the services of other SWSs for getting the tasks done which it can not perform by itself. The SWS requesting services from other SWSs can be called as Service Requester (SR) and the other SWSs satisfying the need of SR can be called as Service Providers (SPs). Before taking the services from SP, in addition to performing the discovery, selection and composition processes, the SR may also needs to perform the negotiation with the SP to establish an agreement over the various attributes like price, quality, time-period, reliability etc. of the service. The utility of the SR/SP can be used in the negotiation process in the decision-making. The utility of a SR/SP represents its happiness or preference [1]. The paper presents a novel computation model for the utility function for SR and SP. The presented model can also be equally applied for the negotiation in multi-agent systems. The model has also been evaluated by comparing it with other similar reported works. In support of the model, a negotiation system which uses the proposed utility model in the decision-making for negotiation process has also been implemented.

The remainder of the paper is organized as follows. Section-2 deals with the some of similar works already reported in the literature. The proposed utility model has been presented in the section-3. Section-4 deals with the evaluation of the proposed model along with the implementation of a negotiation system based on the proposed utility model and the work has been concluded in the section-5.

2 Related Works

Many works are available in the literature which addresses the use of utility functions for negotiation in multi-agent systems. Out of others, some of them to name are: [3], [4], [5], [6], and [7]. However, their works can be useful for the negotiation between SWSs, but they are not directly addressing it. The work in [3] has used the concept of utility theory and uses combination of ease utility and financial utility in the negotiation process. [4] have presented the concept of marginal utility gain and marginal utility cost to structure the search process and to find the solution which maximizes the agents' combined utility. The work uses a multi-attribute utility function into the negotiation process. SCENS [5], a Secure Content Exchange Negotiation System, enables the sharing of sensitive multimodal digital data residing in the distributed digital repositories. Their work proposes the use of utility functions in the negotiation process. [6] in their works have presented an agent based, multi-attribute negotiation model for large-scale construction project supply chain coordination. They have used the concept of utility theory and their negotiation model consists of three processes: attributes evaluation, utility determination, and attribute planning. The work by [7] presents a utility function which also considers the Quality of Service level and provides special consideration to the various attributes involved in the telecommunication services such as quality of medium, type of medium etc. Similar to these reported works, this paper also presents a utility model helpful in the negotiation process for the decision-making. The paper presents a utility model using multiple attributes for the utility-calculation and can be used for the negotiation between SWSs as well as in multi-agent systems. The presented model is based on a novel understanding that if the price, response-time and other such parameters are changed appropriately in accordance with the change in quality, then the utility for that proposal should remain intact. The model presents the utility-calculation using very basic values which are easily available in a negotiation system such as values of price, response-time, quality etc.

3 Utility Model

The utility function should be designed in such a way that it produces such numerical value which increases or decreases to represent the more or less happiness or preference of SR/SP. The SR/SP should be indifferent to the various combinations of values of the different attributes in proposal which produces same utility [1]. So, utility function should be such that it produces same utility value for this type of combinations. Because, for a proposal with attributes (price, quality), if the quality is improved then the corresponding price can also be increased in the required ratio. So, if the price has been increased in the required ratio only, then the utility should remain intact. Let us take a simple example. Let a SWS has utility u for a proposal pr with price value p and quality q and price and quality are related to each other by one-to-one ratio i.e. the ratio in which quality is increased, the price also increased by same ratio. Now, if quality is improved to $1.5q$ and the price also increased to $1.5p$ then the utility value should remain the same i.e. u. Our proposed utility function is based on the same understanding.

The utility of a SWS depends upon values of various attributes of the service. The presented utility function is dependent on the multiple attributes of the service. We have considered three main attributes of a service i.e. price, quality, time-period (response time), so utility can be expressed as a function of these attributes, $utility(price, quality, response-time)$. Further, the price of a service depends upon the quality of service and the response-time. It is likely that the service provider will expend more resources to provide a higher quality or to complete request in lesser response-time, and to maintain profitability it will want to recoup its extra costs by raising the price for the service [1]. The service provider may also require more response-time if the quality-level is increased. So, following relations will hold:

$$price \propto quality \qquad \ldots (1)$$

$$price \propto \frac{1}{response-time} \qquad \ldots (2)$$

$$response-time \propto quality \qquad \ldots (3)$$

If $P_{initial}$, $Q_{initial}$, $T_{initial}$ be the price, quality, and response-time of a service, then using the above discussion, the relations for calculating the new price and new response-time of service after the change in quality can be derived. So, if Q_{new} is the new quality required, then the percentage change in quality can be represented as follows:

$$\Delta Q = \frac{Q_{new} - Q_{initial}}{Q_{initial}} * 100 \qquad \ldots (4)$$

Where, ΔQ is the percentage-change in quality and holds $0 \le \Delta Q \le 100$.

Now, using relation (3), the percentage change in response-time can be calculated as:

$$\Delta T = \frac{K_{TQ} * \Delta Q}{100} \qquad \ldots (5)$$

Where, ΔT is the percentage-change in time due to quality change and it holds $0 \le \Delta T \le 100$. K_{TQ} is the constant which has value $0 \le K_{TQ} \le 100$. Its value is decided by the service provider. It represents the percentage of the percentage-change in quality (ΔQ) with which the response-time should be changed. It means that if the percentage-change in quality (ΔQ) is 80 and K_{TQ} is equal to 40, then the percentage-change in response-time (ΔT) will be 32. The K_{TQ} = 100 implies that the response-time and quality has one-to-one ratio and response-time should be equally changed as change in quality. The K_{TQ} = 0 implies that response-time is not dependent on the quality.

So, the new response-time should be:

$$T_{new} = T_{initial} + \left(\frac{T_{initial} * \Delta T}{100} \right) \qquad \ldots (6)$$

In other form, the T_{new} can be represented as:

$$T_{new} = T_{initial} + \left(\frac{T_{initial} * \frac{K_{TQ}}{100} \left(\frac{Q_{new} - Q_{initial}}{Q_{initial}} * 100 \right)}{100} \right) \qquad \ldots (7)$$

… (2)
… (3)

Now, based on the relation (1), the percentage change in price due to quality change can be derived as follows:

$$\Delta Pq = \frac{K_{PQ} * \Delta Q}{100} \qquad \ldots (8)$$

… (4)

Where, ΔPq is the percentage change in price due to quality-change and it holds $0 \le \Delta Pq \le 100$. K_{PQ} is the constant which has value $0 \le K_{PQ} \le 100$. Its value is decided by the service provider. It represents the percentage of the percentage-change in quality (ΔQ) with which the price should be changed. It means that if the percentage-change in quality (ΔQ) is 80 and K_{PQ} is equal to 70, then the percentage-change in price (ΔPq) will be 56. The K_{PQ} = 100 implies that the price and quality has one-to-one ratio and price should be equally changed as change in quality. The K_{PQ} = 0 implies that price is not dependent on the quality.

So, the new price after taking the quality-change into consideration will be:

$$P_{qnew} = P_{initial} + \left(\frac{P_{initial} * \Delta Pq}{100} \right) \qquad \ldots (9)$$

In other form, the P_{qnew} can be represented as:

$$P_{qnew} = P_{initial} + \left(\frac{P_{initial} * \frac{K_{PQ}}{100} \left(\frac{Q_{new} - Q_{initial}}{Q_{initial}} * 100 \right)}{100} \right) \qquad \ldots (10)$$

The equation (9) and (10) represent the new price after the affect of quality-change. On changing the quality, if the response-time has been changed according to the equation (7), then there should not be any change in price due to response-time change, but if the change in response-time is not according to the equation (7), then this alteration of response-time from the T_{new} will also affect the price. The percentage change in price due to change in response-time can be calculated as follows:

If actual new response-time is T_{ANew}, then the percentage change in response-time from the required response-time T_{new} will be:

$$\Delta Ta = \frac{T_{new} - T_{ANew}}{T_{new}} * 100 \qquad \ldots (11)$$

Where, ΔTa is the percentage alteration of the response-time from the required response-time T_{new} and it holds $0 \le \Delta Ta \le 100$.

Now, based on the relation (2), the percentage change in price due to alteration in the required response-time can be calculated as follows:

$$\Delta Pt = \frac{K_{PT} * \Delta Ta}{100} \qquad \ldots (12)$$

Where, ΔPt is the percentage change in price due to alteration in response-time and it holds $0 \le \Delta Pt \le 100$. K_{PT} is the constant which has value $0 \le K_{PT} \le 100$. Its value is decided by the service provider. It represents the percentage of the percentage-change in response-time (ΔTa) with which the price should be changed. It means that if the percentage-change in response-time (ΔTa) is 30 and K_{PT} is equal to 30, then the percentage change in price (ΔPt) will be 9. The K_{PT} = 100 implies that the price and quality has one-to-one ratio and price should be equally changed as alteration in response-time. The K_{PT} = 0 implies that price is not dependent on the change in response-time.

So, the new price after taking the effect of change in required response-time should be as shown in (13):

$$P_{tnew} = P_{initial} + \left(\frac{P_{initial} * \Delta Pt}{100} \right) \qquad \ldots (13)$$

In other form, the P_{tnew} can be represented as:

$$P_{tnew} = P_{initial} + \left(\frac{P_{initial} * \frac{K_{PT}}{100} \left(\frac{T_{new} - T_{ANew}}{T_{new}} * 100 \right)}{100} \right) \qquad \ldots (14)$$

It can be inferred from equation (13) and (14) that if the actual response-time (T_{ANew}) is more than the required response-time (T_{new}), then the price should be decreased, but if the actual response-time (T_{ANew}) is less than the required response-time (T_{new}), then the price need to be increased.

The new price after considering the effect of change in quality as well as the change in response-time will be as shown in (15):

$$P_{new} = P_{initial} + \left(\frac{P_{initial} * \frac{K_{PQ}}{100} \left(\frac{Q_{new} - Q_{initial}}{Q_{initial}} * 100 \right)}{100} \right) + \left(\frac{P_{initial} * \frac{K_{PT}}{100} \left(\frac{T_{new} - T_{ANew}}{T_{inew}} * 100 \right)}{100} \right) \qquad \ldots (15)$$

The above derived equations can be used for the calculation of utility for SR and SP. Consider that SR has some proposal $\langle P_{initial}, Q_{initial}, T_{initial} \rangle$ and values of various constants K_{PT}, K_{PQ}, K_{TQ}, on which SR agrees. These values can be maintained in the service profile of SR. Let $\langle P_{offer}, Q_{offer}, T_{offer} \rangle$ be the proposal obtained by SR from SP. The offered quality Q_{offer} can be treated as the new quality Q_{new} and offered response-time T_{offer} as the actual response-time T_{ANew} and then using equations (4) to (15), the value for required price P_{new} can be calculated, which is the value of price considered appropriate by the SR for given quality and response-time. This value of price P_{new}, which has been calculated by considering both the quality change and response-time change, will represent level which is preferred by SR or at which SR is happy for given quality and response-time. Whereas, P_{offer} is the offered price for given quality and response-time. So, the ratio of P_{new} and P_{offer} will represent the happiness/preference level of SR, which is also represented by the utility [1]. Hence, the utility of SR can be represented as:

$$Utility_{SR} = \frac{P_{new}}{P_{offer}} \quad \ldots (16)$$

From the equation (16), it can be inferred that if the offered price is more than the required price, then the utility of SR will be less than 1 and the proposal will not be accepted.

In the similar fashion, the utility for SP can be calculated. The only difference is that in the case of SP, the offered price should be more than or equal to the required price, for the proposal to be acceptable. Hence, the utility of SP can be represented as:

$$Utility_{SP} = \frac{P_{offer}}{P_{new}} \quad \ldots (17)$$

From the equation (17), it can be inferred that if the offered price is less than the required price, then the utility of SP will be less than 1 and the proposal will not be accepted.

4 Evaluation and Implementation

The paper mainly focuses on the derivation of multi-attribute utility functions for the SR and SP, which can be useful in the decision-making during negotiation between SWSs. The presented model can be evaluated by comparing it against the reported similar works. [7] have proposed a utility function especially useful for the telecommunication domain. But, their presented function does not seem to calculate the concrete final value of utility, as they have represented the utility in the form of other utility values. They have presented the total utility of a service combination S by following equation: $u(S) = \sum_{c} k_c u_c$, where k_c is the weight of a content-section and u_c is the utility associated with a content-section. Further, the u_c has been computed as the weighted sum of the utilities of constituent medias, $u_m(q_m)$, by following equation: $u_c = \sum_{m \in M_c} \rho_m^c u_m(q_m)$, where ρ_m^c is the weight of medium m. But, no discussion has been found on computation of $u_m(q_m)$. The utility models presented by [3] and [4] do not consider the interdependence of different attributes over each other such as effect of change in quality over the price, response-time etc. [5] have presented a utility function just as a simple weighted sum of values of various attributes. Their function have no provision for considering the interdependence of different attributes and will produce different utility value even when the price or other such factors are changed according to the change in quality. The utility model presented by [6] represents the target utility in the form of other utility values. Their model can be helpful in the utility determination, but does not seem to provide concrete results for utility value. They have presented the target utility, TU, as: $TU = U_{BOW} + CS$, where U_{BOW} is the utility of own decision-making and Concession Step (CS) is determined by: $CS = \beta(1 - \mu / U_{BOW})(U_{BOT} - U_{BOW})$, where U_{BOT} is the utility of other participant's decision-making, μ is the minimal utility, and β is the negotiation speed. No discussion has been provided by them on the calculation of parameters such as U_{BOW} and U_{BOT}. The proposed utility model tries to fulfill the shortcomings mentioned above. The proposed model is based on a novel understanding that if the price, response-time or other such factors are changed appropriately according to the change in the quality, then the utility should remain unchanged. Further, the proposed utility model considers multiple attributes and is flexible and adaptable to consider other attributes also in utility-calculation. The utility model presents the formalization of various parameters in the form of values of basic attributes such as price, quality etc., which are easily available during the negotiation process enabling the calculation of concrete value for utility. Hence, the presented utility model is more reliable, can provide more accurate decision-making, and is more in line with the practical manual negotiation process.

To support the proposed utility model, we have implemented a prototype negotiation system which uses the presented utility model for decision-making during negotiation process. The system provides the negotiation between SWSs. The system has been implemented using Java [8] technology and the service profiles of SR and SP are implemented in OWL (Web Ontology Language) [9] using Jena [10]. Fig. 1 shows the negotiation of SR with one of SP 'Jet Travels (http://www.jettravels.com)'. The table in step 3 in figure 1 shows the offers from SP and SR to each others and the corresponding utility values calculated using the proposed utility model.

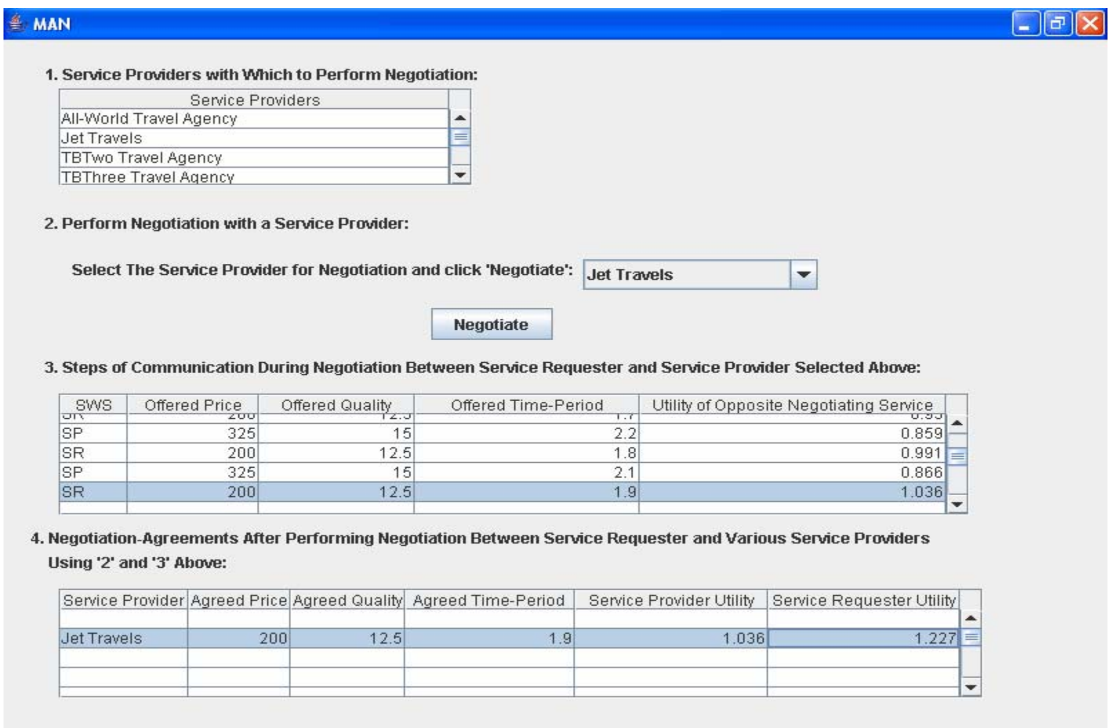

Fig 1. Using proposed utility model

The values of various weights and the initial values of attributes are stored in the respective service profiles of SR and SP. Steps 4 in the figure presents a table showing the final agreement parameters after the negotiation has been successful in the step 3. The table shows the utility of both SR and the SP for the agreed proposal. It can be seen that the proposal is accepted only if the utility value is more than one for both SR and SP.

5 Conclusion

The main focus of the paper is the presentation of a utility model for calculation of the utilities of negotiating semantic web services. The proposed model presents the multi-attribute utility functions for the both service requester and service providers. The presented utility functions also consider the interdependence of various attributes by considering the change in price, response-time etc. due to change in quality. The work has been evaluated by comparing it against the earlier reported similar works and the betterment has been reported. A prototype system has also been implemented which uses the proposed utility model for decision-making during the negotiation between semantic web services. Our future work involves developing a multi-attribute negotiation approach for negotiation between semantic web services, which uses the utility model presented in this paper.

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