THE VALIDATION OF A DYNAMIC SERVICE COMPOSITION MODEL USING A SIMPLE GAME

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Abstract: Service composition is fast becoming a dynamic process where the selection of service elements and their subsequent composition happen at run time. A number of models have been proposed that support dynamic composition. The big issue lies in the validation of such models. A straightforward method of validating such models is to put together a service composition comprising of actual service elements and testing the efficacy of the application. However, this is not always feasible because of the expenses involved in such an experiment combined with the legal and privacy issues with the service providers.

In this paper, we propose a novel idea wherein the validation of a dynamic service composition model can be done using a simple 'Ambitious Traveler' game. The game comprises the selection from a set of predefined transportation services using a dynamic composition model and separately by a group of volunteers who serve as customers. The selections of the two are compared and whosoever makes a better selection gets a higher score.

The game is simple and may be modified to validate dynamic systems of other kinds as well. The specific approach and game described in this paper is currently under development.

1 INTRODUCTION

Service composition is the combination of simple service elements to form larger, more complex composite applications. The composite application so formed could further be combined in a recursive manner with other service elements or compositions to form even larger applications. The service elements that partake in such compositions are usually determined in advance, and the composition process comprises monitoring the flow of data/messages between these services. Such composition processes with predetermined service elements are called static compositions.

The bigger challenge is in putting together service compositions where the selection of service elements is done at the time of composition. Such dynamic compositions deal with the issue of appropriate service selection based on the requirements of the customer along with monitoring the flow of messages/data between the selected service elements. The fact that the attributes of the service elements are varying as are the requirements of different customers, makes this task even more complex.

A number of service composition models have been proposed to tackle this issue (Silva et al., 2009)(Colombo et al., 2006). These models typically arrive at selection decisions based on a logical assessment of the customer requirements and their conformance with the attributes of the potential service elements. Our research also comprises a service composition model. In our approach, we mathematically combine multiple Quality of Service (QoS) attributes of the potential service elements based on the importance placed on the respective QoS attributes by the customer. Further, we also incorporate the interactions between the service elements in the domain. All this together gives us a factor called *Affinity* upon which dynamic service selections are made. Details of our technique are given in Section 3 of this paper.

This brings us to the main topic of this paper which is the validation of such a composition model. An intuitive approach to this would be to utilize the model to dynamically put together an actual service composition. This however is not always practicable, especially in an academic set-up, given privacy and legal issues that govern the usage of commercially available service elements.

We therefore synthesized a game which we call the *Ambitious Traveler*, that involves putting together

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individual service elements at run time just like the dynamic service composition scenario. Furthermore, the game assigns 'scores' to players on the basis of their performance. A group of volunteers are requested to play the game and their respective scores are noted. Subsequently, the game is played with the service selection decisions being made using our composition model. The score of our model is compared with those of the volunteers. If the model consistently outperforms the players, the model's efficacy is validated.

The remainder of this paper is organized as follows: Section 2 is a discussion on other techniques of validation for dynamic service composition systems. Section 3 is a description of our 'Affinity' model for dynamic service composition. This is the model that needs to be validated. In Section 4, we describe the *Ambitious Traveler* game which will serve as a means to validate our model and which can be modified to validate other dynamic systems as well. Section 5 discusses possible improvements and enhancements which we envisage in the game in the future. Finally, Section 6 concludes the paper.

2 RELATED WORK

In this section we discuss a few strategies for validation of dynamic systems that have been adopted by researchers in the past.

Colombo et al. (Colombo et al., 2006) tackle the issue of dynamic composition where the service elements do not always behave along expected lines. They provide an extension to the BPEL language in the form of the 'SCENE platform' which addresses this issue. The proposed platform is validated forming an application using a set of real services and observing the behaviour of the application.

Silva et al. (Silva et al., 2009) propose the DynamiCos framework which incorporates the requirements of different customers to dynamically put together personalized services. To validate the proposed framework they put together an extensive prototype of the framework which enables services to be deployed and be published in a UDDI-like registry.

In their paper Eid et al. (Eid et al., 2008) describe a set of benchmarks against which to assess various frameworks of dynamic composition. The set of benchmarks is comprehensive and is broadly categorized into three parts: input subsystem, composition subsystem, and execution subsystem. A composition model or framework that scores well against these benchmarks is considered good.

Shen et al. (Shen et al., 2007) present the Web Service, Role and Coordinator (WSRC) model to handle dynamism in web service compositions. In this model, the process of service composition is divided into three layers: Service, Role, and Coordinator. To validate the model, the authors describe a case-study of a vehicle navigation system which comprises a global positioning system and a traffic control service.

These are a few of the validation techniques in use for dynamic composition models and frameworks. Of these techniques, the ones that are accurate are quite complex like the prototype that the authors of DynamiCos put together or the service composition put together out of real services for the SCENE platform. On the other hand, the validation techniques that are simple like the case-study in the WSRC model seem ineffective.

The validation technique proposed in this paper, the Ambitious Traveler game, on the other hand is quite simple as it comprises an elementary game with straightforward steps and instructions. Despite this, it is quite precise and is able to quantitatively express the performance of the dynamic composition model.

3 THE 'AFFINITY' MODEL FOR SERVICE COMPOSITION

In this section we describe our 'Affinity' model for service composition. It is specifically for the validation of this composition model that the Ambitious Traveler game (described in Section 4) is used. The game can, however, be modified appropriately and be used for the validation of other dynamic systems as well.

3.1 Assumptions on the Service Domain

In our 'Affinity' model for service composition, certain simplifying assumptions have been made about the service domain from which the service elements are selected. First, our approach assumes that the service elements taking part in the composition process are already available in the service domain. The approach therefore does not look into the issue of 'discovering' the service elements. The reader interested in the process of service discovery is pointed to (Wu, 2008) for an exhaustive discussion on the subject.

The potential service elements, which are assumed to have been already discovered, are represented as arranged in a tiered fashion as shown in Figure 1. Each tier or level corresponds to a specific functionality of the composite application. All the discovered service elements that correspond to the respective functionality are placed at that level. The ar-

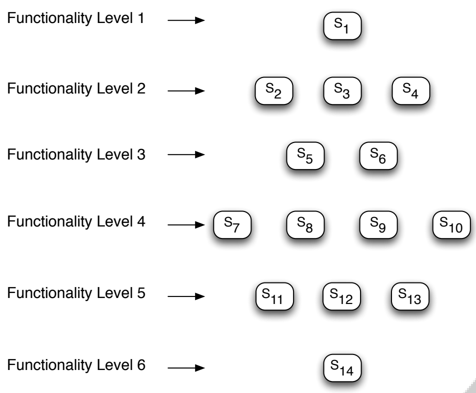

Figure 1: The service domain.

rangement of the functionality levels from top to bottom follows the order in which the functionalities are invoked in the composite application. This means that the functionality of a given level *follows* the functionality of the level immediately above it, and *is followed* by the functionality of the level immediately below it, in the composite application. An example of a Trip-planner application is shown in Figure 2 to give an idea of what a real world service domain might look like (the service names in Figure 2 are fictitious).

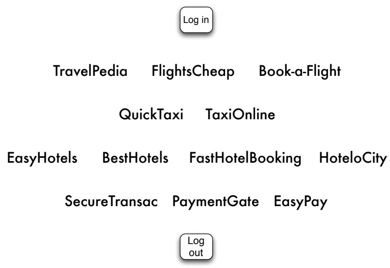

Figure 2: The service domain of the trip-planner application.

We introduce a factor called 'Coupling' which connects a service element at a given functionality level in the domain to a service element at the next lower functionality level as shown in Figure 3 . Coupling is an expression of the 'working compatibility' that exists between service elements at adjacent functionality levels and depends on high level factors such as business relationships between the providers of the respective service elements, as well as low level technological compatibility between the potentially interacting elements. Coupling values are assigned through expert judgement based on a comprehensive assessment of the service element and its relationship with the service elements at the adjacent levels. A Coupling value of 1 is assigned if no special relationship exists between two service elements, and higher values are assigned for stronger relationships (a Coupling value of 0 is assigned if one service element does not acknowledge the presence of the other).

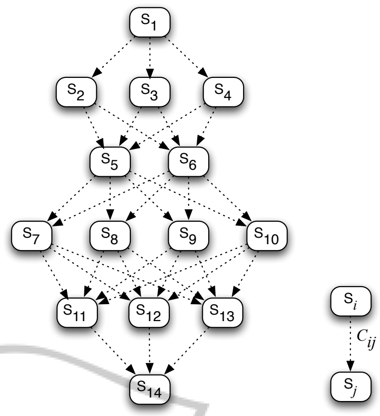

Figure 3: The service domain with arcs representing Coupling and the effective workflow.

3.2 Service Selection and Composition

In our approach the selection of service elements from the functionally equivalent ones at each level of the domain is done utilizing the Quality of Service (QoS) attributes. The service element whose QoS attributes conform most closely with the requirements of the customer is the one selected.

The first task is to enable the customers to express their QoS requirements. Our approach requires the customer to attach a 'weight' to each QoS factor depending on the extent to which the factor is desired in the composite application. For example, if one of the QoS factors is reliability, and the customer requires a highly reliable service, the parameter (say α) representing the weight of reliability needs to be assigned a high value. This is akin to a 'tuning knob' mechanism wherein the QoS requirements of the customer are looked upon as a set of control knobs. One knob is assigned to each factor. The customer may turn the knobs depending upon the degree to which he/she desires the QoS factors in the composite application.

The next task is to make the appropriate selections of service elements based on the expressed QoS requirements of the customer. To do this the value of the QoS factors in each of the potential service elements needs to be calculated. Any number and type of QoS factors may be considered. In our work, we have chosen four QoS factors: Reliability, Waiting-time, Reputation, and Cost.

Reliability (Rel.) is the first QoS factor considered. In our work, the reliability of individual service elements has been calculated taking into account the influence that the presence of other service elements in the domain have on them (Srivastava and

Sorenson, 2010a). Waiting-time (Wait-time) is the next factor considered. The waiting-time for a service element is the time that a request for the service has to wait from the time of invoking the service element to the time the service begins. The waiting-time for a request at a service element is calculated as the ratio of the length of the 'request-queue' to the average completion-rate of the service element (Srivastava and Sorenson, 2010b). The Reputation (Reput.) of a service element is considered to be a valuable attribute and is the next factor that is incorporated in the service selection process. In our work, the reputation of a service element is calculated on the basis of feedback collected from customers who have used the service element. Finally, the Cost of the service element is utilized in making an appropriate selection. The cost of a service element is calculated taking into account the functional and non-functional attributes of the element along with the influence of its environment.

The four QoS factors so calculated for each service element along with the weights assigned by the concerned customer to each QoS factor are used to calculate a factor called 'Affinity' between every pair of potentially interacting service elements. The $Affinity_{ij}$ between a potential invoking service element i and a potential invoked service element j is a function of the values of the QoS factors calculated for the invoked service and the value of coupling between the two services. It is shown in equation (1)

$$Affinity_{ij} = Coupling_{ij} \cdot \frac{\{Rel._j\}^{\alpha} \cdot \{Reput._j\}^{\gamma}}{\{Wait\text{-}time_j\}^{\beta} \cdot \{Cost_j\}^{\delta}} \quad (1)$$

α, β, γ, and δ are the weights assigned respectively by the customer to the QoS factors: Reliability, Waiting-time, Reputation, and Cost. With the value of Affinity so calculated, the service elements for the composite application are selected following a Greedy approach (Cormen, 1990). The service element selected for each functionality is the one with the maximum value of Affinity with the previously selected element.

4 THE 'AMBITIOUS TRAVELLER' GAME

In this section, the 'Ambitious Traveller' game is described which serves as a simple and inexpensive means of validating our service composition model. This is only a preliminary description of the game. We expect the game to go through two or more evolutions before a production-ready version is completed. The emphasis here is on the idea and efficacy of using games like these to validate dynamic systems.

4.1 Description of the Game

The motive of a player in the Ambitious Traveller game is to travel as much as possible around the globe given a limited amount of money and limited time. The winner is the player who manages to travel the maximum distance. The structure of the game is described in Figure 4. The player starts from an 'origin' and has to travel to the first city on the list: Paris in the figure. To travel to Paris, the player has the option to choose between taking a flight, a car, a train, or a boat. Each of these means of transportation has its pros and cons. For example, a flight would save time but would probably be expensive and possibly require the player to wait longer before getting a reservation; a train on the other hand would be much more affordable but would be much slower.

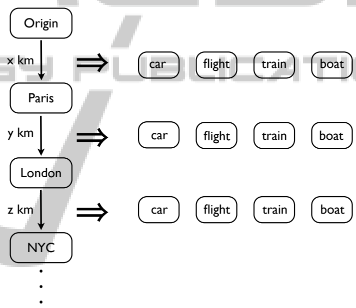

Figure 4: An overview of the Ambitious Traveler game.

On getting to Paris, the next destination for the player is London. To get to London, again the player has to take a decision on the means of transportation. This is continued until the player either runs out of money, or time. In either case, the distance travelled by the player until then is noted. Every player is given a large number of travel opportunities. On each opportunity, the player starts from the origin with a limited amount of money and time and attempts to travel as far as possible. After the player is done with all his travel opportunities, the average of the distances travelled on all the opportunities is the final score of the player. The larger the final score the better the player has done in making his transportation selections.

The service domain in this game is the transportation service (flight, car, train, and boat) between every pair of travel points. These transportation services are analogous to the service elements at each functionality level in the service domain of our composition model described in the previous section. Just like in the composition model where a service selection has to be made at each functionality level to put together the composite application, in this game the player has to make a selection between the available transportation services to travel further. Every transportation service, like the service elements in the composition model, has an associated reliability, a waiting-time, a reputation, and an associated cost. The player has to make a trade-off between one or more of these QoS attributes every time he makes a transportation selection.

In the following portion, we describe how the selection of one transportation service over another based on its QoS attributes impacts the final score (the total distance traveled) of the player.

Reliability. Every transportation service in the game has an associated 'fail-rate'. The transportation services are randomly made to fail at rates proportional to their respective fail-rates. The value of the fail-rate of a transportation service is modified every time the service fails. There are no implications of a failure of a transportation service if the service is currently not transporting any player. If however, the transportation service is indeed transporting a player when it fails, the player loses all the money invested in invoking the service and also wastes time as he is sent back to the previous level and has to once again make a transportation selection for the same destination. Therefore, it is beneficial for the player to make a transportation choice which advertises a high degree of reliability.

Waiting-time/Completion-time. Whenever a player with any of his travel requests makes a transportation choice, there is a possibility that the transportation service is currently in use by another request and the player has to wait. Waiting for a large time period results in the player wasting time which is a limited resource in the game and adversely affects the score of the player. It is important therefore for the player to select a transportation service incorporating the length of the waiting queue at the service.
The other factor that influences the time resource of the player is the travel time or the service completion-time. A good choice here results in the player wasting very little time in covering the distance between two cities and thus has a favorable influence on his score. A bad choice has the opposite effect. The service time of the transportation should also therefore be taken into account while making a service choice.

Reputation. Every player that uses a transportation service in the game is expected to give his feedback on the service. This feedback is usually a figure that the player feels appropriate out of a maximum of 5. The feedback of the players forms the basis of deriving a reputation value for a service. The reputation is a quantitative expression of the overall 'feel' that the player gets while using the service. Each service has a reputation value which is the average of the feedback values assigned by all the players that have used the service. The reputation value of a transportation service serves as an indicator of the quality of previously experienced service to subsequent players while making their service selection.

Cost. Cost is an overarching factor that has a direct influence on the choice of the player. A cost is associated with each transportation service based on its overall functional and non-functional attribute values as well as on the environment in which the service is being used. The cost is a dynamic factor and its value keeps varying. A player who selects a transportation service that has a high cost, risks wasting money which is one of the two limited resources in the game; however by choosing an expensive service the same player could be gaining in terms of time, the other limited resource. Therefore, there is a trade-off which the player has to decide upon using his judgement.

4.2 The Game as a Validation Tool

To use the Ambitious Traveler game described in the previous sub-section as a validation tool for our service composition model, the game will be played in three different modes: *(i)* by volunteers making their own service selection decisions at each stage of their travel; *(ii)* by volunteers providing their quality factor weightings and have our service composition model make service selections; and *(iii)* by playing the game making random service selections at each travel opportunity.

The scores of each of the three scenarios are noted for a large number of travel requests. A high score by our composition model when compared to the volunteer(s) score or the random-selection strategy score serves to validate the model. In the following subsections, we will describe how the game is played by each of the participants mentioned above.

4.2.1 Game Played by Volunteer(s)

We request one or more volunteers to play the game. The first task that the volunteer needs to do is mention the importance that he places on each of the QoS attributes: Reliability, Waiting-time, Reputation, and Cost. If the volunteer customer is comfortable doing this, he is asked to express this importance in terms of values assigned to respectively α, β, γ, and δ. If the customer is unable to do this, he is asked a set of questions on whose basis values are assigned to the four parameters.

Next, the volunteer starts sending service requests into the transportation service domain. Every time that the volunteer has to make a decision regarding the means of transportation, he is shown the following information regarding the potential transportation services available: *(i)* the current fail-rate of each of the transportation services, *(ii)* the queue length of other waiting requests at each service, *(iii)* the travel time of each of the potential transportation services, *(iv)* the reputation of each of the services, *(v)* the cost of the services, and *(vi)* a map showing the current location of the customer and the location that he needs to travel to (to give him an idea of the geographical features separating the locations). This is shown in Figure 5. On the basis of all these factors the volunteer makes an intuitive judgement on which of the available services to select. The volunteer is appealed to take his decision conforming as far as possible to the weights (α, β, γ, and δ) assigned by him to the four QoS attributes.

This process is repeated for the volunteer for a large number of travel requests. The total distance travelled by each request is noted and finally the average of these distances is the score of the volunteer. If there are several volunteers, the same is done for the other volunteers also.

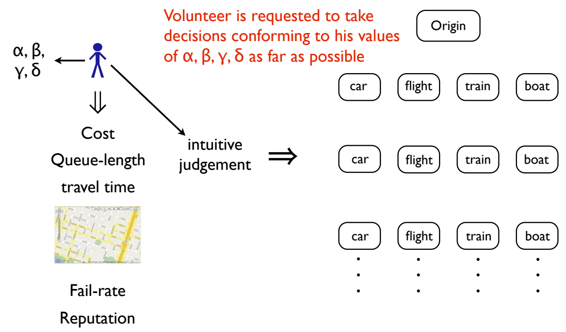

Figure 5: The Ambitious Traveler game as played by the volunteer.

4.2.2 Game Played by our Composition Model

We next play the game with our Affinity model for service composition taking the selection decisions. At each service level, the value of Reliability for each of the potential transportation services is calculated using the technique described in (Srivastava and Sorenson, 2010a); the waiting-time is calculated as the ratio of the queue-length of the waiting-requests at each service to the completion-rate (in this case travel rate) of the service (Srivastava and Sorenson, 2010b); the reputation for each transportation service is calculated using the feedback collected from previous requests; and finally the cost is dynamically calculated for each of the transportation services taking all the functional and non-functional attributes and the environment of the service into account.

The Coupling between the service elements at adjacent levels is determined by logical judgement. For example, in Figure 4, the Coupling between any of the transportation services to London and the 'car' service at the level of NYC (New York City) would have a value of 0. This is because it would be absurd to use a car as a means of transportation between London and NYC given the expanse of the Atlantic Ocean between the two cities!

With the values of the QoS attributes and Coupling calculated, the equation for calculating the Affinity between service levels shown in equation (1) is utilized. The values of α, β, γ, and δ as specified by the volunteer are used.

The selections using the composition model are done for travel requests that are identical to those sent out by the volunteer(s) and under identical circumstances. The total distance covered by each request is noted and the average of the distances of the requests gives the final score of the composition model.

4.2.3 Game Played at Random

To ensure that the scores of the above two selection techniques are actually relevant and meaningful, the game is also played with the service selections being made at random. The random selections are done for requests that are identical to the requests of the volunteer(s) and the total distance travelled in each case is noted. The average of these distances gives the score when the selections are made at random.

The scores of the three selection techniques are compared. If the scores of our Affinity model for service composition are statistically significantly better than the other two, this serves to validate the technique. Even if the scores of our composition model are comparable with those of the intuitive judgement of the volunteer, it suggests that our automated selection method is useful given the significant overhead associated with the thought and judgement selection process of individual volunteers.

5 FUTURE ENHANCEMENTS TO THE GAME

The Ambitious Traveler game in its present form is quite simple and is robust as a validation tool for dynamic systems from a customer point of view. We however envisage a much greater role for the game in the future with possible extensions and enhancements.

As the game stands now, it comprises volunteers who serve as customers that make selections given a service domain that is static. An extension that could have a far reaching impact could be to also have a set of volunteers who would serve as providers. These providers would be responsible for setting up transportation services that would be used by customers to move from one city to another. The providers could adjust the cost of the services to ensure a comfortable profit margin even while keeping up with competition. The other quality attributes of the services could also be adjusted depending upon the resources available and with an eye on the level of demand. The provider would benefit immensely from the game by being in a position to try out various marketing strategies in a synthetic set up and getting a handle on what to expect.

A more ambitious enhancement to the game could be by developing it as an application for a web mapping service like Google maps (GoogleMaps, 2010). Prospective service providers could set up fictitious services at different locations on the map. Prospective customers could use such services, provide feedback, choose between competing services, and much more. A virtual world on the web mapping application could be set up with prospective customers and providers indulging in transactions and activities that would normally occur in a real situation. All this would give both the customer and provider a 'feel' for the situation and ultimately enable them to make much better business decisions.

6 CONCLUSIONS

The Ambitious Traveler game described in this paper serves as an inexpensive and convenient means to validation of a dynamic service composition model. This game may easily be modified to suit the purpose of validation of any other kind of dynamic system model also. Although the game described is still under development, the idea of utilizing such a game for validation purposes is unique and novel.

The game described is currently good for validating the service composition model from the customer point of view. It ensures that the interests of the customer are upheld and the service composition formed conforms to the requirements of the customer. We hope that with a few enhancements, the game could be used to validate a model that allows the provider also to make changes to the available service domain. Such a game could be used to uphold the interests of both the customer and provider and would therefore ensure a degree of co-value to both sides.

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