Summaries of Survey Papers

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1 A Survey on Bio-inspired Algorithms for Web Service Composition [2]

This paper discusses research endeavours on Web service composition using the following techniques: Ant Colony Algorithm, Genetic Algorithm, and Particle Swarm Optimisation. However, before presenting information on each of these techniques it gives an overview of how the problem of Web service composition is represented (i.e. the models of web service composition). The paper notes that one of the limitations of this field is that there is no standard way to compare the performance of two different approaches, so it is difficult to tell whether one has an advantage over the other.

1.1 Terminology

All systems that make use of Web services use the principle of *late binding*. According to this principle, the functional needs to be fulfilled by a given service are represented by an abstract service, and at runtime this is replaced by a concrete instance, often based on QoS measures. A composition can be created either using *local optimisation*, when the performance of each service in the composition must be within a specified standard, or using *global optimisation*, when the performance of the overall composition must meet a given specification. Creating a service composition with global constraints is regarded as an NP-hard problem. Solutions to compositions can be calculated using *exhaustive* (i.e. deterministic) methods, which are expensive and scale poorly but yield the best composition, or *approximate* (i.e. nondeterministic) methods, which are cheaper but cannot guarantee that the best composition will be found.

1.2 Models for Web Service Composition

At its core, Web Service Composition can be considered a *combinatorial optimisation* problem, where the objective is to find the best subset from a finite set of elements. Apart from *graphs*, other representations for composition problems exist. These include the *Knapsack problem*, where a number of items must be selected to be a part of a solution set in order to maximise the total positive features of the set while keeping the negative features at a minimum, and *multi-objective/multi-dimensional* optimisation, where several different goodness functions are considered simultaneously, leading to a Pareto set of results that presents different trade-offs for each goodness measure. In this set, no

result can be considered better than any other result, and no goodness measure can be improved in a result without reducing some of its other goodness measures.

1.3 Ant Colony Algorithm

This algorithm is a representation of the behaviour of ants. These ants search optimal paths between a start and an end node in a directed acyclic graph (DAG), and leave pheromones denoting the best composition path within the DAG (note that the actual implementation of the pheromone mechanism varies from work to work, including the use of different pheromones for different QoS attributes). In this approach, each atomic Web service is typically represented as a node in the graph, and the QoS constraints are typically represented as weights applied to the graph edges. However, different graph representations have also been presenting. Persisting on local optima is a potential problem with this technique, and its efficiency is not the highest.

1.4 Genetic Algorithm

Genetic algorithms are a popular choice for tackling combinatorial optimisation problems, and thus have been widely applied to the problem of Web service composition. A common representation for atomic Web services uses integer programming, meaning that each service is represented as an integer. More specifially, linear integer programming is typically used, restricting all constraints and fitness functions to be linear. The encoding scheme for a composition is commonly done as an array of integers, but some authors have attempted to use a matrix to also include semantic information (?). Researchers also commonly investigate QoS representations, operators and fitness function variations to be applied to GA. An observed problem with the GA technique is that it tends to prematurely converge to solutions, thus preventing it from exploring further possibilities.

1.5 Particle Swarm Optimisation

Hybrid approaches have been attempted to improve the efficiency and optimisation power of PSO alone. Additionally, some authors have investigated the use of a PSO that is environment-aware. PSO may present the problem of not fully optimising solutions (premature convergence).

2 Service Selection in Web Service Composition: A Comparative Review of Existing Approaches [1]

There exist two main approaches for automated Web service composition: *workflow-based approaches* and *AI planning-based approaches*. In workflow-based approaches, the idea of an abstract business process that is to be completed with concrete services is central. AI planning-based approaches, on the other hand, do not typically require this abstract view. Composite service selection is considered an /textitNP-hard problem, meaning that the solution to large problems

is not likely to be found with reasonable computation times. This is typically addressed by reducing the search space.

2.1 Lifecycle of a Typical Workflow-based WSC Solution

A workflow-based WSC solution involves the following steps:

1. *Goal specification:* The user's goal and preferences for the composition are specified. An abstract workflow is generated, showing details about data flow and functionality, and the QoS requirements are determined based on the user's information.

2. *Service discovery:* Candidate concrete services that are functionally and non-functionally suitable to fill the slots in the abstract workflow are discovered in a service repository. At this stage, candidates have varying quality.

3. *Service selection:* A technique is employed to find which discovered services best fulfil each slot in the abstract workflow specified earlier, and a concrete Web service composition is generated.

4. *Service exection:* An instance of the concrete composition generated above is made executed.

5. *Service maintenance and monitoring:* The created instance is constantly monitored for failures and/or changes to the composing atomic services.

2.2 Optimisation-based WSC Approaches

These approaches assume that QoS settings have already been made and are unchangeable during the period when service selection takes places. They can also be referred to as *QoS-aware* WSC approaches. One possible approach is *Integer Linear Programming*, where integers denote which services have been chosen to execute a specific task. This approach can be executed using existing solvers, but this representation does not scale well. *Genetic algorithms* are another possibility. In this case, solutions can either be represented as a single dimension (a single execution path in the composition) or as a matrix (all execution paths in the composition). GA is unconstrained, which may lead to solutions that are not functionally valid, therefore penalties must be included into the fitness function employed. *Constraint optimization* is another way to conceptualise WSC. The algorithm in this technique is run according to a collection of constraints, searching for the solution that fits within those constraints. This method is thought to be more scalable than those previously discussed. Finally, *stochastic programming* is discussed. This approach takes the non-deterministic nature of QoS attributes into account (e.g. variations in response time, price, etc) by using a risk measure. The objective function then incorporates this measure in the creation of a risk-aware composition.

2.3 Negotiation-based WSC Approaches

These approaches assume that QoS settings can be modified after they have been initially set. In the context of Web service composition, automated negotiation is

used both for adjusting the details of Service Level Agreement contracts and for dynamically selecting the best provider for particular Web services. This type of negotiation requires an organised framework, including a negotiation object (the service with QoS attributes), a standardised protocol, and a decision-making model that implements a negotiation strategy.

2.4 Hybrid Approaches

These approaches are not based purely on optimisation or negotiation, and two of them are discussed in this paper. The first one combines *optimisation and configuration*, that is, it executes an optimisation but allows users to specify ranges of values that are accepted for each QoS attribute (as opposed to a single value). The second one combines *optimisation and negotiation*, that is, if the optimisation fails to encounter a solution with the requested QoS standards, a negotiation process is started.

References

[1] Mahboobeh Moghaddam and Joseph G Davis. Service selection in web service composition: A comparative review of existing approaches. In *Web Services Foundations*, pages 321–346. Springer, 2014.

[2] Lijuan Wang, Jun Shen, and Jianming Yong. A survey on bio-inspired algorithms for web service composition. In *Computer Supported Cooperative Work in Design (CSCWD), 2012 IEEE 16th International Conference on*, pages 569–574. IEEE, 2012.