Equitable Solutions in QoS-aware Service Optimization

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ABSTRACT

Web services QoS optimization problem using the concept of Lorenz dominance is addressed. Lorenz solutions are equitable and well balanced. Such an approach could simplify the Decision Maker's choice. Evolutionary detection of Lorenz solution seem to be an appealing one. Some state-of-the art MOEAs are slightly modified for addressing the QoS optimization problem. Lorenz solutions drastically reduce the number of solutions in the Pareto set, and thus the decision costs.

Categories and Subject Descriptors

D.2.8 [**Software Engineering**]: Metrics

Keywords

Service Oriented Computing, Lorenz dominance, Differential Evolution, Quality of Service

1. INTRODUCTION

Service Oriented Architecture (SOA) implementations are more and more popular, diverse and widespread in enterprise distributed environments. This fact is due to their technical advantages over more traditional methods of distributing computing.

The QoS optimization problem is multi-objective by its nature. The user might prefer to see several good solutions (Pareto optimal) and decide which is the best for himself/herself while the standard optimization algorithms offer only one solution. It is more natural to let the user decide if he/she wants to pay a specific known price than aggregating the objectives and ask him/her to specify *a priori* how important is the price for him/her and without knowing the precise price value. By using multi-objective optimization, it is not necessary to define a priori an aggregation function. This is not a trivial task and different users may have different preferences, for instance about the price versus quality requirements.

One important step in the optimization process is the choice of the final solution. A Decision Maker (DM) must pick the suitable solution from a final solution set found by the algorithm. In many cases the DM is not an expert thus this final step is not easy for him. By replacing Pareto dominance with an equitable dominance relation in the search process the size of the final solution set is greatly reduced, helping the non expert DM in the final step. This fact motivated us to perform the research presented in this paper.

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2. THE PROBLEM OF SERVICES QOS OPTIMIZATION

A composite service can be described as a process that involves the execution of several activities according to a workflow. A web service is associated to each activity.

Executing an activity means invoking a service. For each activity, which is assimilated to an *abstract service*, several *concrete services* exist. Each concrete service has different QoS properties. For describing the QoS we use the following (widely used) parameters *response time, rating, availability* and *cost*.

The QoS of the composite service is obtained by aggregating the QoS of the component services. Examples of aggregation rules are given in [1, 3, 5].

Given m abstract services and n concrete services for each abstract service, there are n^m possible combinations. Thus, finding the QoS optimal solution is an non-deterministic polynomial-time hard (NP-hard) problem.

3. EVOLUTIONARY ALGORITHMS APPLIED TO SERVICE COMPOSITION

Taboada et al. propose a custom genetic algorithm called Multi-objective Multi-State Genetic Algorithm [4] for general system design optimization. The system components have different performance levels, cost, weight and rating.

Yao et al. [5] propose an approach based on Non dominated Sorting Genetic Algorithm-II (NSGA2) algorithm. A solution is encoded using an integer vector, similar to [1].

Li Li et al. [3] propose another multi-criteria oriented approach based on the Strength Pareto Evolutionary Algorithm (SPEA2) algorithm. Three criteria are considered: response time, cost and availability.

One major objection to use multi-objective optimization algorithms is the size of the solution set. The final selection of the solution is let to the end user who might not be an expert thus confusing him. One way to avoid this drawback is to use Lorenz dominance [2] which reduces substantially the solution set by using equitable preference relation to differentiate between solutions.

4. NUMERICAL EXPERIMENTS

State-of-the-art algorithms are considered for detecting Pareto front. The Lorentz variants (L-X) of these algorithms are used for detecting Lorenz equitable solutions. The implementation is based on ECJ framework version 20. Prior to the experiments, the implementations of all used algorithms have been validated with well-known benchmarks.

Service are defined by abstract BPEL processes. These processes have various complexity and are randomly generated. The complexity is adjusted by increasing the number of abstract services from *10* to *50*.

The genome used to encode the solution is an integer vector for NSGA2 and SPEA2. Each gene is an integer value representing the index of the concrete service used. DE algorithms use floating point encoding to resolve problems in a continuous domain so we need to use a discrete version.

Experiments with two criteria. A first set of experiments was performed using a complex workflow (including sequences, split, join, loops and switch blocks) and five algorithms: NSGA2, SPEA2 and GDE3, POSDE. Population size, for all algorithms, is limited to *150* individuals, they evolve for *250* generations, for DE algorithms CR=0.4 and F=0.3. For these experiments we considered only two criteria: rating and (time + cost). The results for 10 abstract services and 20 concrete services are depicted in Figure 1.

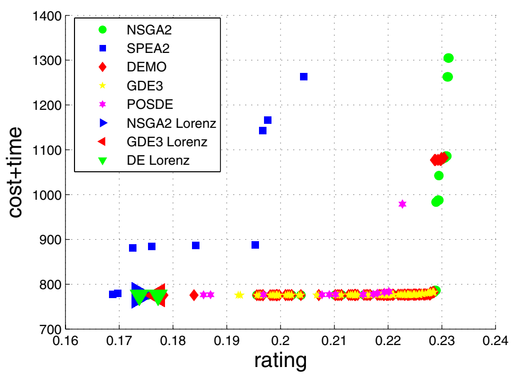

Figure 1: Pareto front for a BPEL process with m=10 abstract services and n=20 concrete services per abstract service. NSGA2, GDE3 and POSDE give a similar Pareto set but GDE3 and NSGA2 assure a better spread of solutions.

NSGA2, GDE3 and POSDE give a similar Pareto set but GDE3 and NSGA2 assure a better spread of solutions. SPEA2 set is dominated with respect to the Pareto sets found by the other algorithms. When using Lorenz dominance the final solution set contains one equitable solution.

Experiments with three criteria. A second series of experiments was performed using more complex workflows and with three independent criteria: response time, rating and cost. For all the algorithms the populations size was limited to *150* individuals, evolved for *300* generations, for DE algorithms CR=0.4 and F=0.3. The size of the archive for POSDE, SPEA2 is 150 in order to assure a fair comparison. In a case with with m=10 abstract services and n=20 concrete services per abstract service (low complexity) all algorithms behave similarly.

A more complex scenario involving m=20 abstract services, each of them having n=40 concrete services was evaluated. The added complexity makes it harder to find a good Pareto Set. SPEA2 doesn't find a good set while the DE approaches and NSGA seems to converge to the same PF. In a case with m=40 abstract services and n=40 concrete services per abstract service. Only NSGA2 and GDE3 are able to find a Pareto front and assure good diversity of solutions. The other algorithms produce a PS in which most solutions are dominated.

5. CONCLUSIONS

Lorenz dominance is a refinement of Pareto dominance and it is natural in fair optimization problems. Using Lorenz dominance in the search process can relieve the Decision Maker from the burden of choosing a good solution from a large set of final solution (that may contain a large number of solutions).

Several multi-objective optimization algorithms are considered for solving the services QoS optimization problem considering Lorenz dominance. L-NSGA2 seems to have the best performances demonstrated by the evaluation metrics. But L-NSGA2 proven to be also the slower algorithm. Therefore, DE approaches seem to be a better choice for addressing complex problems. The results have shown that the Lorenz dominance concept reduces the number of solutions and the decision making is easier.

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