Computing Pareto Optimal Agreements in Multi-issue Negotiation for Service Composition

(Extended Abstract)

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ABSTRACT

In a market of services, customers require Service Based Applications (SBAs) with specific QoS constraints usually expressed as end–to–end requirements. Here, we show that mechanisms used to find Pareto optimal agreements can be extended in order to compute them also in the case of negotiation for market–based service composition, where different provider agents compete to provide the same service. Moreover, we discuss how these mechanisms allow a customer agent to concurrently negotiate with all available service provider agents.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent systems

Keywords

Electronic markets, Bargaining and Negotiation.

1. INTRODUCTION

A *Service-Based Application* (SBA) is a complex business application composed of self-contained, loosely-coupled services, characterized also by quality aspects, i.e., by non-functional features referred to as *Quality of Service* (QoS) attributes. In a market of services the number of services available on the network, having similar functionalities but different QoS values, will significantly increase. When SBAs are requested with specific QoS values, usually expressed as end–to–end requirements, their provision becomes a decision problem to select the services providing the required functionalities such that the QoS of the resulting application satisfies the customer's requirements. In this work, we show that when using agents automated negotiation to select the set of service providers providing the appropriate services, (near) Pareto–optimality of the negotiation outcomes can be computed, as proven in [3], also when more provider agents compete to provide the same service. Moreover, a *weighted orthogonal bidding strategy* to find an agreement, if it exists is introduced, so allowing the customer agent to concurrently negotiate with all service provider agents for each service.

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2. NEGOTIATION FORMALIZATION

Let us consider an SBA request with n (with $n \geq 2$) Abstract Services (ASs), i.e., a specification of a service functionality, each one characterized by m QoS issues (with $m \geq 1$), and k (with $k \geq 1$) Service Providers (SPs) agents for each of the n ASs, representing the owners of a specific service. A Service Compositor agent (SC), acting on behalf of the user, specifies constraint C_j on the request $\forall j \in m$.

In order to select the services with suitable QoS values, an automated iterative negotiation process among the SC and the SPs able to provide the services with the requested functionalities takes place on the services QoS values [2]. At each iteration, the SPs formulate new offers, and the SC evaluates them. SC accepts a set of offers, one for each AS, if their aggregated value satisfies the global constraints for each QoS issue, so leading to an agreement ($\mathbf{A}$). If an agreement is reached at round t, the negotiation ends successfully, otherwise all the offers are rejected and the SC engages all SPs in another negotiation iteration until a deadline is reached.

Here, we focus on the collaborative part of the negotiation, i.e., when agents make trade–off, starting from the *orthogonal bidding strategy* proposed in [3] where each agent involved in the negotiation computes a so called *reference point*, representing its desired bid to reach an agreement, when keeping fixed all the other agents bids. It allows the agent to select, step by step, a new offer on its indifference curve as the point that minimizes the Euclidean distance between the curve and the reference point. In our reference market–based scenario, it is likely that for each AS more than one SP may issue offers, so we adopt the heuristic method proposed in [1] to select, at each iteration, a set of agents (one for each AS) providing a set of promising offers. Reference points for each AS are computed by the SC since SPs do not know neither the offers of other agents, nor the global constraints set by the user. These reference points are sent to all SPs providing the same AS, so involving them again in the next negotiation iteration.

Definition 1. The *reference point* for the SPs corresponding to an AS_i and to m additive issues at round t is:
$\mathbf{r}_i^t = (C_1 - \sum_{k \in N-\{i\}} b_{k,1}^t, \ldots, C_m - \sum_{k \in N-\{i\}} b_{k,m}^t)$.

where $\mathbf{b}_k^t$ is the last bid of agent $k \in N - \{i\}$ selected for the considered combination at that round.

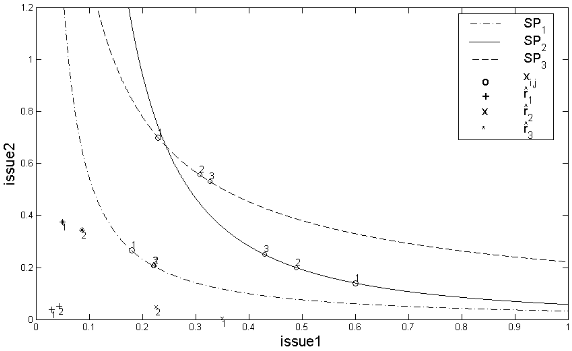

Figure 1: Trends of $\hat{\mathbf{r}}_i^t$ in 2 negotiation rounds.

Definition 1 is the same as in [3], so the same theorems apply also in our case provided that reference points are calculated with respect to the set of selected offers at each round, i.e. the near Pareto optimal agreement is referred to the agents providing the set of selected offers at the considered round. Different sets of selected offers may lead to different Pareto optimal agreements.

3. WEIGHTED REFERENCE POINTS

To compute its reference point, an SP for a given AS waits for the offers of the others SPs of the remaining ASs, since reference points are computed keeping fixed the other offers. This mechanism is undesirable when the number of ASs increases. So, we propose that reference points referred to a given round t are computed relying only on the offers available at the previous round as follows:

Definition 2. The *timed reference point* for the SP_i corresponding to an AS_i at round $t+1$ is:
$\bar{\mathbf{r}}_i^{t+1} = (C_1 - \sum_{k \in N-\{i\}} x_{k,1}^t, \ldots, C_m - \sum_{k \in N-\{i\}} x_{k,m}^t)$.
where, for simplicity there is one SP agent for each AS.

Unfortunately, timed reference point do not guarantee the convergence of the orthogonal bidding strategy, but an oscillatory behavior may arise due to the fact that reference points are concurrently computed at round t. This prevents the adjustment of bids for each AS, step by step, within the same round that is a prerequisite for the convergence to an agreement. To obtain the convergence of the orthogonal bidding strategy, while keeping the possibility to concurrently compute reference points, it is necessary to provide SPs with reference points that allow for different adjustments of bids, in terms of different "weights" that depend on the issue values of the offers with respect to their aggregated values.

For this reason, we introduce a new reference point, named the *weighted reference point* ($\hat{\mathbf{r}}_i^t$) as follows:

Definition 3. The *weighted reference point* for the SP_i corresponding to an AS_i at round $t+1$ is $\hat{\mathbf{r}}_i^{t+1} = (\hat{r}_{i,1}^{t+1}, \ldots, \hat{r}_{i,m}^{t+1})$, where $\hat{r}_{i,j}^{t+1}$ is equal to $\dfrac{x_{i,j}^t}{\sum_{k=1}^n x_{k,j}^t} \cdot \bar{r}_{i,j}^{t+1} = \omega_{i,j}^t \cdot \bar{r}_{i,j}^{t+1}$

The term $\omega_{i,j}^t$ represents the weight of the issue value at time t compared to the aggregated value of all the bids for that issue, and $\bar{r}_{i,j}^{t+1}$ is the timed reference point of Definition 2.

The convergence of each weighted reference point to the corresponding bid in the agreement is not proven, but the following Lemma holds.

LEMMA 1. *A set of offers $\mathbf{x}^t = (\mathbf{x}_1^t, \ldots, \mathbf{x}_n^t)$ is an agreement at round $t \iff$ the weighted reference point $\hat{r}_i^{t+1}$ for the SP_i corresponding to an AS_i Pareto dominates its weighted bid at the previous round, i.e. $\hat{r}_{i,j}^{t+1} \geq \omega_{i,j}^t x_{i,j}^t$ with $j \in M$.*

PROOF. Assuming that $\mathbf{x}^t$ is an agreement, then $\sum_{i=1}^n x_{k,j}^t \leq C_j$, hence $\frac{C_j}{\sum_{i=1}^n x_{k,j}^t} \geq 1$. Substituting Definition 2 in Definition 3, it follows that $\hat{r}_{i,j}^{t+1} = \omega_{i,j}^t \cdot r_{i,j}^{t+1} = \frac{x_{i,j}^t}{\sum_{k=1}^n x_{k,j}^t} \cdot (C_j - \sum_{k=1}^n x_{k,j}^t + x_{i,j}^t) = x_{i,j}^t \cdot (\frac{C_j}{\sum_{k=1}^n x_{k,j}^t} - 1 + \frac{x_{i,j}^t}{\sum_{k=1}^n x_{k,j}^t})$. From the agreement condition, the first term in the parenthesis is grater than one, so leading to the following inequality: $\hat{r}_{i,j}^{t+1} = x_{i,j}^t \cdot (\frac{C_j}{\sum_{k=1}^n x_{k,j}^t} - 1 + \frac{x_{i,j}^t}{\sum_{k=1}^n x_{k,j}^t}) \geq x_{i,j}^t \cdot \frac{x_{i,j}^t}{\sum_{k=1}^n x_{k,j}^t} \geq x_{i,j}^t \omega_{i,j}^t$.

If $\hat{r}_{i,j}^{t+1} \geq \omega_{i,j}^t \cdot x_{i,j}^t$ then $\omega_{i,j}^t \cdot \bar{r}_{i,j}^{t+1} \geq \omega_{i,j}^t \cdot x_{i,j}^t$ by definition of weighted reference point. Given the definition of ω and timed reference point, the inequality can be rewritten as $\frac{x_{i,j}^t}{\sum_{k=1}^n x_{k,j}^t} \cdot (C_j - \sum_{k=1}^n x_{k,j}^t + x_{i,j}^t) = x_{i,j}^t \cdot (\frac{C_j}{\sum_{k=1}^n x_{k,j}^t} - 1 + \frac{x_{i,j}^t}{\sum_{k=1}^n x_{k,j}^t}) \geq \omega_{i,j}^t \cdot x_{i,j}^t$. Hence, $\frac{C_j}{\sum_{k=1}^n x_{k,j}^t} - 1 + \omega_{i,j}^t \geq \omega_{i,j}^t$, and $\frac{C_j}{\sum_{k=1}^n x_{k,j}^t} \geq 1$, that is an agreement. $\square$

Hence, when trading–off among possible offers with the same utility, the weighted orthogonal bidding strategy leads to an agreement (see Figure 1).

4. CONCLUSIONS

When service provision occurs in a competitive and dynamic market of service providers, software agent negotiation is a suitable approach to select services. We proposed a variation of the orthogonal bidding strategy presented in [3], introducing the notion of weighted reference point to still guarantee the possibility to find an agreement, also when negotiating with more providers of the same service. In this way, negotiations can be carried out concurrently, so avoiding the significant increase in negotiation time when the number of abstract services increases.

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