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Enacting agent-based services for automated procurement

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Abstract

Negotiation events in industrial procurement involving multiple, highly customisable goods pose serious challenges to buying agents when trying to determine the best set of providing agents' offers. Typically, a buying agent's decision involves a large variety of constraints that may involve attributes of a very same item as well as attributes of different, multiple items. In this paper we present *iBundler*, an agent-aware service offered to buying agents to help them determine the optimal bundle of received offers based on their business rules. In this way, buying agents are relieved with the burden of solving too hard a problem and concentrate on strategic issues. *iBundler* is intended as a negotiation service for buying agents and as a winner determination service for reverse combinatorial auctions with side constraints. Furthermore, we assess the computational cost added by employing agent technology in the development of *iBundler* to characterise the type of negotiation scenarios that it can acceptably handle.

Keywords: Negotiation; e-Commerce; Open agent systems; Scalability; Artificial intelligence; Agents; Integer programming; Optimization

1. Introduction

With the advent of the Internet, agent researchers envisioned a promising future to software agents in a large variety of e-commerce settings. Business automation, decision-making and enterprise integration have been widely claimed, among others, as suitable tasks for agents. Time has proven those expectations were too enthusiastic in general, but in our view there are indeed e-commerce scenarios where agent technology can prove valuable (Hohner et al., 2003). In particular, agent technology can contribute to the automation of complex tasks and to the assistance of parties involved in intricate decision-making processes in procurement scenarios. One particular, key procurement activity carried out by most companies concerns the negotiation of both direct and indirect goods and services.

Although negotiation is a key procurement mechanism, most agent-based services deployed have focused on infrastructure issues related to negotiation protocols and ontologies. Thus, the lack of agent-based decision support for trading agents that help improve current trading practices hinders the adoption of agent technology in procurement scenarios.

Furthermore, while a significant number of agent-based applications for electronic commerce have been presented to the agent community during the last years, little attention has been devoted to analysing the practical benefits and shortcomings of agent technology when applied to such domain. Little effort has been devoted to study the applicability of state-of-the-art agent technology to develop actual-world e-commerce applications. Thus, we believe that it is necessary to assess the computational cost added by agent technology in this type of applications so that we can diagnose the improvements required by state-of-the-art agent technology.

For this purpose we report on a case study that intends to shed some light on both matters. In this paper we fully describe *iBundler* (introduced in Giovannucci et al., 2004),

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an agent-aware decision support service acting as a combinatorial negotiation solver (solving the winner determination problem) for both multi-item, multi-unit negotiations and auctions. Thus, the service can be employed by both buying agents and auctioneers in combinatorial negotiations and combinatorial reverse auctions (Sandholm et al., 2002), respectively. To the best of our knowledge, *iBundler* represents the first agent-aware service for multi-item, multi-unit negotiations. In fact, *iBundler* was designed to be employed as: (1) an open agent platform within the Agentcities. RDT[1] project that could be discovered, communicate, and offer services to any FIPA compliant agent (FIPA, http://www.fipa.org); (2) an agent façade to *Quotes* (Reyes-Moro et al., 2003), a commercial negotiation tool, to allow for the participation of third-party business agents in actual-world procurement events. In both cases, we study the computational cost of agent awareness for the *iBundler* negotiation service so that its users are aware of the type of negotiation scenarios that *iBundler* can acceptably handle when buying and providing agents are involved. This exercise has also included the determination of those general or domain-dependent measures that can help reduce the cost of the service. At this aim, we have measured the performance in time and memory of *iBundler* through a wide range of artificially generated negotiation scenarios. For each negotiation scenario we sampled at several stages both the time and memory that *iBundler* employed to handle it. We have interestingly observed that the management of ontologies is a rather delicate issue that actually causes a significant overload. Furthermore, we have also observed that the design of highly expressive, compact bidding languages can definitely help cut down the computational cost for any agent-aware negotiation service considering combinatorial scenarios.

The paper is organised as follows. Section 2 introduces the market scenario where buyers and traders are to negotiate, along with the requirements, preferences, and constraints they may need to express. Next, a formal model of the problem faced by the buyer (auctioneer) based on the description in Section 3 is provided. Thereafter, Section 4 details the computational realisation of the agent service as an agency. The description of the service focuses on the agency's architecture, the AUML specification of the interaction protocol offered by the service to trading agents, and ontological issues that needed to be considered in order to offer buying and providing agents the expressiveness required to enact their business rules. Next, Section 5 details the evaluation scenarios arranged to test *iBundler*, and presents and thoroughly discusses the tests' results. Finally, Section 6 summarises our contributions and draws conclusions on our evaluation.

[1]The Agentcities. RDT project's objectives were to create an on-line, distributed test-bed to explore and validate the potential of agent technology for future dynamic service environments (http://www.agentcities.org/EURTD).

2. Market scenario

Although the application of combinatorial auctions (CA) to e-procurement scenarios (particularly reverse auctions) may be thought as straightforward, the fact is that there are multiple new elements that need to be taken into consideration. These are new requirements explained by the nature of the process itself.

While in direct auctions, the items to be sold are physically concrete (they do not allow configuration), in a negotiation involving highly customisable goods, buyers need to express relations and constraints between attributes of different items. On the other hand, multiple sourcing is common practice, either for safety reasons or because offer aggregation is needed to cope with high-volume demands. This introduces the need to express constraints on providers and on the contracts they may be awarded. Not forgetting the provider side, providers may also impose constraints or conditions over their offers.

Consider a buyer intending to buy 200 chairs (any colour/model is fine) for the opening of a new restaurant, and at that aim we employ an e-procurement solution that launches a reverse auction. If we employ a state-of-the-art CA solver, a possible resolution might be to buy 199 chairs from provider A and 1 chair from provider B, simply because it is 0.1% cheaper and it was not possible to specify that in case of buying from more than one provider a minimum of 20 chairs purchase is required. On the other hand, the optimum solution might tell us to buy 50 blue chairs from provider A and 50 pink chairs from provider B. Why? Because although we had no preference over the chairs' colour, we could not specify that regarding the colour chosen all chairs must be of the same colour. Although simple, this example shows that without modelling natural constraints, solutions obtained are seen as mathematically optimal, but unrealistic.

Next, we identify the capabilities required by buyers in the above-outlined negotiation scenario to express their preferences:

(1) *Negotiate over multiple items*. A negotiation event is usually started with the preparation of a request for quotation (RFQ) form, which details the requirements (including attribute values as well as drawings and technical documentation) for the list of requested items (goods or services).

(2) *Offer aggregation*. An RFQ item can be multiply sourced (acquired from several providers), either because not a single provider can satisfy the whole demand or because of buyers' explicit constraints (see below).

(3) *Business sharing constraints*. Buyers might be interested to restrict the number of providers that may have each RFQ item awarded, either for security or strategic reasons. It is also common practice to constraint the contract volume a single provider may gain per item.

(4) *Constraints over single items*. Every RFQ item is described by a list of negotiable attributes. Since: (a) there exists a degree of flexibility in specifying each of these