iBundler: An Agent-based Decision Support Service for Combinatorial Negotiations

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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 multiple items. In this paper we describe *iBundler*, an agent-aware negotiation service to solve the winner determination problem considering buyers' and providers' constraints and preferences.

Introduction

Consider the problem faced by a buying agent when negotiating with providing agents. In a negotiation event involving multiple, highly customizable goods, buying agents need to express relations and constraints among attributes of different items. Not forgetting the provider side, providing agents may also wish to impose constraints or conditions over their offers. Once a buying agent collects all offers, he is faced with the burden of determining the winning offers. We have implemented *iBundler* (introduced in (Rodríguez-Aguilar *et al.* 2003) and thoroughly described in (Giovannucci *et al.* 2004)) with the aim to relieve buying agents from solving such a problem. *iBundler* is 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. The service can be employed by both buying agents and auctioneers in combinatorial negotiations and combinatorial reverse auctions respectively. Furthermore, it extends current combinatorial auction (CA) models by accommodating both operational constraints and attribute-value constraints. At this aim, new ontological issues have been considered in order to empower the expressiveness offered by negotiation objects and offers to incorporate buyers' and providers' business constraints. Its deployment over the Agentcities (http://www.agentcities.org) network was awarded the prize of the Best Application of the 2003 Agentcities Worldwide Agent Technology Competition.

iBundler Service Features

As we explained above buyers and providers need to express their business rules. In the following we make explicit the support offered by *iBundler* to express buyers constraints:

Negotiation over multiple items. A negotiation event is usually started with the preparation of a request for quotation (RFQ) form, which details the requirements.

Offer aggregation. An RFQ item can be multiply sourced.

Business sharing constraints to restrict the number of providers that may have each RFQ item awarded.

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 attributes (e.g. several values are acceptable); and b) multiple offers referring the very same item can be finally accepted; buyers need to impose constraints over attribute values.

Constraints over multiple items. In daily industrial procurement, accepting certain configuration for one item might affect the configuration of a different item (e.g. to ensure compatibility between products). Hence, buyers need to express constraints and relationship between attributes of different RFQ items.

Specification of providers' capacities. Buyers cannot risk to award contracts to providers beyond their capabilities. At this aim, they must require to have providers' capacities per item declared.

Analogously, providers are endowed with a rich bidding language as follows:

Multiple bids per item. Providers might be interested in offering alternate sub-conditions/configurations for the very same good, i.e., offering alternatives for a same request. A common situation is to offer volume-based discounts. This means that a provider submits several offers and each offer only applies for a minimum (maximum) number of units.

Combinatorial offers. Economy efficiency is enhanced if providers are allowed to offer (bid on) combination of goods. They might lower the price, or improve service assets if they achieve to get more business.

Multi-unit offering. Each provider requires to specify his willingness to sell over/below a minimum/maximum number of units.

Homogeneous combinatorial offers. Combinatorial offering may produce inefficiencies when combined with multi-unit offering. Thus a provider may wind up with an award of a small number of units for a certain item, and a large number of units for a different item, being both part of the very same offer (e.g. 10 chairs and 200 tables). It is desirable for

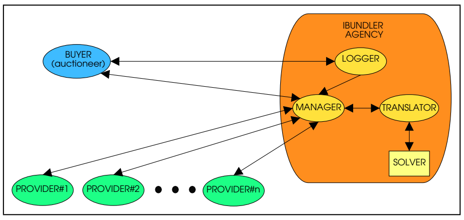

Figure 1: Architecture of the *iBundler* agency

providers to be able to specify homogeneity with respect to the number of units for complementary items.

Packing constraints. It is often not possible to serve an arbitrary number of units. Thus, providers require to specify their packing sizes.

Complementary and exclusive offers. Providers usually submit XOR bids, i.e., exclusive offers that cannot be simultaneously accepted. A second type of constraint, AND, allows to express volume-based discounts (e.g. first 1000 units at $2.5 p.u. and then $2 each).

iBundler implementation

The *iBundler* service has been implemented as an agency composed of agents and software components that cooperatively interact to offer a negotiation support service. The service can be employed by both buyers and auctioneers. Figure 1 depicts the components of the agency along with the fundamental connections of buyers and providers with the service. Next we make explicit the main functionality of its members:

[Logger agent]. It represents the interface of the *iBundler* agency to the world. It manages the access to the agency for both buyers and providers.

[Manager agent]. Agent devoted to providing the solution of the problem of choosing the set of bids that best matches a user's requirements. It offers the following services: brokering service to forward buyers' requirements (RFQs) to selected providers; collection of bids; winner determination in a combinatorial negotiation/auction; and award of contracts on behalf of buyers. Furthermore it bundles each RFQ and its bids into a negotiation problem to be conveyed to the Translator agent; and extracts the solution to the negotiation problem handled back by the Translator agent.

[Translator agent]. It is in charge of translating problems expressed in FIPA compliant format into XML format, understandable by the Solver component, and vice versa.

[Solver component]. The XML specification is parsed into an MIP formulation and solved using available MIP solvers. Our formulation of the problem (Giovannucci *et al.* 2004) can be regarded as similar to the binary multi-unit combinatorial reverse auction winner determination problem with side constraints (Sandholm *et al.* 2002). Expressing the problem as an MIP problem with side constraints enables its resolution by standard algorithms and commercially available software. With these considerations in mind the Solver component has been modelled and implemented as a mixed integer program(MIP) problem: a version using ILOG CPLEX 7.1 in combination with SOLVER 5.2; and another version using iSOCO's Java MIP modeler —that integrates GLPK (http://www.gnu.org/directory/GNU/glpk.html).

Our design manages to separate concerns among the three members of the agency. On the one hand, the Manager is strictly devoted to coordination; it represents the façade of the service. Besides, since every negotiation requested by a buyer makes the agency create an instance of the Manager, the service can cope with scalability issues. Thus, if the service is heavily accessed, Managers can synchronise to queue tasks for the Translator. This is in charge of relieving both Managers and Solver from the burden of translating FIPA-compliant specifications into the XML language required by Solver. Notice too that Solver has been implemented as a software component because it was intended to serve for two purposes: as the core component of the *iBundler* agency, and as the winner determination component in a commercial sourcing application (Rodríguez-Aguilar *et al.* 2004).

To implement the *iBundler* agency we used the following technologies: JADE (http://sharon.cselt.it/projects/jade) as the software tool to implement agents, and as the platform where the agency resides and Tomcat 4.1 (http://jakarta.apache.org/tomcat/) as J2EE server to build web interfaces for human traders. The ontology was defined with the aid of *Protege 2000* (http://protege.stanford.edu) and the conversion from ontological objects to Java classes was realized via the *beangenerator* Protege 2000 plug-in (http://www.swi.psy.uva.nl/usr/aart/beangenerator).

Contributions

The implementation of *iBundler* contributes along two main directions. On the one hand, we have incorporated actual-world side constraints to the winner determination problem for combinatorial negotiations. On the other hand, we have realized a new ontology that accommodates both operational constraints and attribute-value constraints for buying and providing agents, offering a highly-expressive bidding language.

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