A Mixed Multi-unit Combinatorial Auctions Test Suite[*]

Andrea Giovannucci
Pompeu Fabra University
andrea.giovannucci@gmail.com

Jesus Cerquides
University of Barcelona
cerquide@maia.ub.es

Ulle Endriss
University of Amsterdam
ulle.endriss@uva.nl

Meritxell Vinyals
IIIA-CSIC
meritxell@iiia.csic.es

Juan A. Rodriguez
IIIA-CSIC
jar@iiia.csic.es

Bruno Rosell
IIIA-CSIC
rosell@iiia.csic.es

ABSTRACT

Supply Chain Formation (SCF) is the process of determining the participants in a supply chain, who will exchange what with whom, and the terms of the exchanges. Mixed multi-unit combinatorial auctions (MMUCAs) offer a high potential to solve SCF problems, and thus be employed for the automated assembly of supply chains of agents. In this paper we present MMUCATS, a test suite for MMUCAs that allows researchers to test, compare, and improve their winner determination algorithms for MMUCAs.

1. SUPPLY CHAIN FORMATION PROBLEM

According to [6], "Supply Chain Formation (SCF) is the process of determining the participants in a supply chain, who will exchange what with whom, and the terms of the exchanges". Combinatorial Auctions (CAs) are a negotiation mechanism well suited to deal with complementarities among the goods at trade. Since production technologies often have to deal with strong complementarities, SCF automation appears as a very promising application area for CAs. However, whilst in CAs the complementarities can be simply represented as relationships among goods, in SCF the complementarities involve not only goods, but also production relationships along several levels of the supply chain.

The first attempt to deal with the SCF problem by means of Combinatorial Auctions (CA) was done by Walsh et al. in [6]. In order to automate SCF, they introduce the notion of task dependency network (TDN) as a way of capturing complementarities among production processes. Although very significant, this work does not allow bidders to express their preferences over bundles of production processes; it does not define a bidding language; and the structure of the supply chain has to fulfil strict criteria (e.g. acyclicity, processes can only produce one output good, etc). In order to overcome these drawbacks, Cerquides et al. introduce in [2] the so-called mixed multi-unit combinatorial auctions (MMUCAs), a generalisation of the standard model of CAs. Rather than negotiating over goods, in MMUCAs the auctioneer and the bidders can negotiate over *transformations*, each one characterized by a set of input goods and a set of output goods. A bidder offering a transformation is willing to produce its output goods after having received its input goods along with the payment specified in the bid. While in standard combinatorial auctions, a solution to the winner determination problem (WDP) is a set of atomic bids to accept, in MMUCAs, the *order* in which the auctioneer "uses" the accepted transformations matters. Thus, a *solution* to the WDP is a *sequence of transformations.* For instance, if bidder *Joe* offers to make dough if provided with butter and eggs, and bidder *Lou* offers to bake a cake if provided with enough dough, the auctioneer can accept both bids whenever he uses Joe's transformation before Lou's to obtain cakes.

MMUCAs do offer a high potential to be employed for the automated assembly of supply chains of agents. However, in order for MMUCAs to be effectively applied to SCF, we must ensure computational tractability while preserving optimality. Unfortunately this is not a straightforward task because, as discussed in [3, 5], the tractability of the WDP is largely affected by the topological structure of the problem (e.g. cycles in the supply chain). In order to address this and other problems, we propose to endow researchers with a test suite where they can investigate computationally efficient solvers for the MMUCA WDP, along the lines of the successful CATS suite [4] for combinatorial auctions.

2. MMUCATS A TEST SUITE FOR MMUCA

MMUCATS has been conceived as a Java-based, graphical test suite for MMUCAs to help researchers test, compare, and improve their winner determination algorithms. In what follows we highlight its most salient features:

Artificial data set generation. MMUCATS encloses an algorithm to generate artificial data sets (as described in [5]) that are representative of the sort of scenarios a WD algorithm is likely to encounter. The algorithm takes inspiration from the structure of supply chains. Thus, it allows: (i) to generate supply chain structures with varying number of *tiers* (levels); (ii) to flexibly distribute transformations between tiers so that transformations vary from very simple to highly *complex* (in terms of goods involved per transformation) between tiers; (iii) to flexibly distribute transformations between tiers so that tiers are connected by different production structures (e.g. cycles or a transformation whose input goods are beyond the preceding tier and whose output goods go beyond the next tier); and (iv) to flexibly distribute bids over transformations so that the *competitiveness* between tiers may vary in order to model dif-

[*] Funded by TIN2006-15662-C02-01,CONSOLIDER CSD2007-0022,INGENIO 2010 and JC2008-00337. Vinyals thanks FPU grant AP2006-04636.

Cite as: A Mixed Multi-unit Combinatorial Auctions Test Suite, Andrea Giovannucci et. al, *Proc. of 8th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2009)*, Decker, Sichman, Sierra and Castelfranchi (eds.), May, 10–15, 2009, Budapest, Hungary, pp. XXX-XXX.

ferent types of markets. Interestingly, the flexibility of our generator makes possible that within the very same supply chain we can find varying degrees of *production complexity*, different *production structures* involving goods from multiple tiers, and varying degrees of *competitiveness*. Although MMUCATS encloses an implementation in MATLAB of the generator, it allows users to incorporate their own generators as long as the generator's output is an XML file that complies with the MMUCATS DTD for WDP instances.

Analysis. MMUCATS provides several graphical facilities for the structural analysis of WDP instances depicting: (i) the *supply chain structure* along with the distribution of goods and transformations between tiers (e.g. see figure 1); (ii) the *bid graph structure* capturing the relationships among bids, goods, stock goods, and goods required as a result of the supply chain operation; (iii) the *transformation dependency graph* showing the dependencies among transformations, as described in [3]; and (iv) the strongly connected components of the tranformation dependency graph.

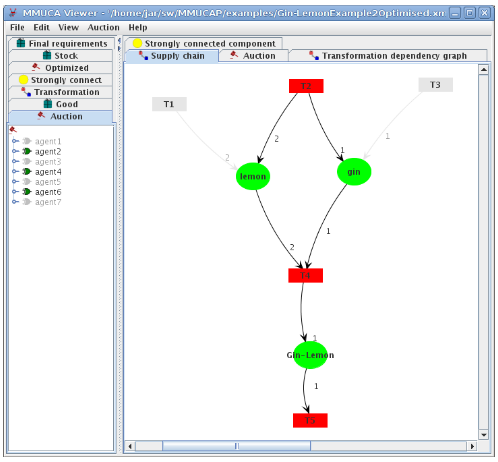

Figure 1: A supply chain sample.

Winner determination. MMUCATS allows researchers to incorporate their winner determination algorithms to solve the WDP instances created by an artificial data set generator. At this aim, we offer two paths. As a first option, we offer an API to convert an XML WDP instance (as output by the generator) or optimal solution (as generated by a solver) into Java data structures and the other way around. Moreover, the API also offers methods translating the Java structure into a GLPK model. To further help developers, the current version of MMUCATS includes the GPLK and CPLEX implementations of the solver described in [3] as sample implementations. As a second option, MMUCATS can realise external calls to solvers capable of reading a file containing an XML WDP instance and producing a file encoding an XML optimal solution. MMUCATS interprets the solutions output by solvers to graphically display the optimal structure of the supply chain, the net benefit of the formation process, and, if available, the time employed by the solver, and the number of decision variables employed.

Animation. Once solved an instance of the WDP, MMUCATS can *animate* the solution to show users how transformations are used along the optimal supply chain and how goods are produced and consumed. This feature is aimed at helping users how the resulting supply chain is expected to behave when enacted.

Automated supply chain generation. MMUCATS allows to automatically generate the workflow for the optimal supply chain structure produced by a winner determination algorithm as an ISLANDER specification [1]. Two major benefits stem from this facility. Firstly, the ISLANDER specification can be readily employed to enact a supply chain as an electronic institution where winning bidders participate with the aid of the Electronic Institutions Development Environment (EIDE) [1]. Secondly, users can also benefit from the simulation facilities provided by EIDE to analyse the expected performance of the resulting supply chain. Figure 2 illustrates the ISLANDER specification generated by MMUCATS for the optimal solution of the WDP represented in figure 1.

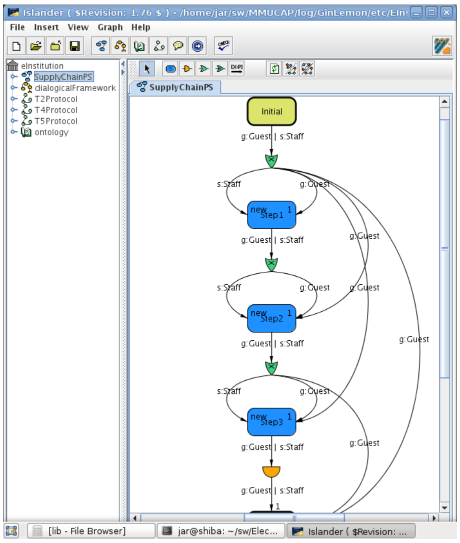

Figure 2: ISLANDER supply chain specification.

3. REFERENCES

[1] J. L. Arcos, M. Esteva, P. Noriega, J. A. Rodriguez-Aguilar, and C. Sierra. Engineering open evironments with electronic institutions. *EAAI*, 18(2):191 – 204, 2005.

[2] J. Cerquides, U. Endriss, A. Giovannucci, and J. A. Rodriguez-Aguilar. Bidding languages and winner determination for mixed multi-unit combinatorial auctions. In *IJCAI*, pages 1221–1226, Hyderabad, India, Jan. 2007.

[3] A. Giovannucci, M. Vinyals, J. A. Rodríguez-Aguilar, and J. Cerquides. Computationally-efficient winner determination for mixed multi-unit combinatorial auctions. In *AAMAS*, pages 1071–1078, 2008.

[4] K. Leyton-Brown and Y. Shoham. *Combinatorial Auctions*, chapter 18. A Test Suite for Combinatorial Auctions. MIT Press, 2006.

[5] M. Vinyals, A. Giovannucci, J. Cerquides, P. Meseguer, and J. A. Rodríguez-Aguilar. A test suite for the evaluation of mixed multi-unit combinatorial auctions. *J. Algorithms*, 63(1-3):130–150, 2008.

[6] W. Walsh and M. Wellman. Decentralized supply chain formation: A market protocol and competitive equilibrium analysis. *JAIR*, 19:513–567, 2003.