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A multi-agent platform for auction-based allocation of loads in transportation logistics

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ABSTRACT

This paper describes an agent-based platform for the allocation of loads in distributed transportation logistics, developed as a collaboration between CWI, Dutch National Center for Mathematics and Computer Science, Amsterdam and Vos Logistics Organizing, Nijmegen, The Netherlands.

The platform follows a real business scenario proposed by Vos, and it involves a set of agents bidding for transportation loads to be distributed from a central depot in the Netherlands to different locations across Germany. The platform supports both human agents (i.e. transportation planners), who can bid through specialized planning and bidding interfaces, as well as automated, software agents. We exemplify how the proposed platform can be used to test both the bidding behaviour of human logistics planners, as well as the performance of automated auction bidding strategies, developed for such settings.

The paper first introduces the business problem setting and then describes the architecture and main characteristics of our auction platform. We conclude with a preliminary discussion of our experience from a human bidding experiment, involving Vos planners competing for orders both against each other and against some (simple) automated strategies.

1. Introduction

Decentralized markets and distributed auctions have received a lot of research interest, as important coordination mechanisms between self-interested agents. Recent research, both by the authors of this paper and many others (Reeves, Wellman, MacKie-Mason, & Osepayshvili, 2005; Robu & La Poutré, 2008; 't Hoen & La Poutré, 2006; 't Hoen, Robu, & La Poutré, 2005) etc. proposes increasingly complex algorithms for bidding and modeling decisions in such agent-mediated auction environments.

Transportation logistics and supply chain management represent challenging and potentially very fruitful areas for the application of agent-based electronic market techniques, such as auctions. The increasing complexity and shifting structure of modern supply chains, as well as increasing competitive pressures in this market has led to an increasing demand and interest in such distributed optimization techniques, involving multiple parties. The practical impact of improved allocation which can be achieved through such techniques can be significant. For example, in the Netherlands, the average transport performance is between 40% and 60%. Improving this utilization rate is also the goal of the DEAL (Distributed Engine for Advanced Logistics) project, which groups together several universities and large logistics service providers in the Netherlands. The work reported here was also carried out in the framework of this project, involving two of the main partners, namely CWI, Amsterdam and Vos Logistics Organizing, Nijmegen, the Netherlands.

1.1. The multi-party logistics domain

Several trends have recently produced a significant impact on the area of transportation logistics. One of these is an increase in competition, with the continual entry of new carriers in the market pushing down expected profit margins. Another one is the increasing complexity and sophistication of modern supply chains. In fact, due to increasing and shifting trade patterns, not only transportation chains have become more dynamic, but also their structure has become increasingly complex.

For example, nowadays it is no longer the case that the company that accepts a transportation order also owns the actual capacity (i.e. trucks) to carry it. Often, multinational companies with large, regular amounts of cargo to be delivered prefer to outsource these orders to other companies that undertake to find convenient delivery options, within a set of pre-negotiated terms. These intermediary logistic companies then negotiate the distribution of these orders with other smaller companies who have the

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actual transportation capacity (which own the actual trucks and hire the drivers). This can be actually a cheaper option in many cases, as smaller transportation companies often do not have the complex cost structure that larger companies have (Robu et al., 2008; van Amstel & Goor, 2003; van der Putten, Robu, La Poutré, Jorritsma, & Gal, 2006).

In standard transportation management literature (van Amstel & Goor, 2003) such distributed supply chains are called multi-party logistics. Existing literature (van Amstel & Goor, 2003) identifies several classes of logistic provider companies, based on the type of services they offer. Although there is some disagreement about the exact usage of the terms, in our approach (and the remainder of this paper) we use the term 3PL company (third-party logistics providers) to denote those that have their own transport capacity (i.e. truck fleet) and plan this own capacity and 4PL company (i.e. fourth-party logistics provider) to denote those companies which "orchestrate" the supply chain, i.e. acquire large sets of orders from large shippers and then re-distribute these orders among a set of other companies with actual transport capacity.

1.2. Company profile

Founded in 1944 as a one-truck company, transporting loads between Oss and Nijmegen in The Netherlands, Vos Logistics has grown into one of the larger logistics service providers in Europe. It has over 3000 trucks, 10000 trailers and containers, 325 storage silos and 2 rail service centers. Vos employs 5000 people working at more than 45 locations throughout Europe, while annual turnover approaches 1 billion euro.[1] The increasing complexity of transportation chains has induced Vos Logistics to offer new solutions to its large corporate customers (shippers), which can now outsource all of their transportation activities to Vos. This lets them avoid the problem of finding and negotiating with individual suppliers, billing, following up orders etc. Another advantage of using this outsourcing service for large shippers is that Vos Logistics has a much better knowledge of the transportation market, so it is better positioned to find suitable sub-contractors. Vos Logistics Organizing from Nijmegen (henceforth abbreviated VLO in this paper) is a subsidiary of Vos Logistics B.V. that was set up in order to handle such complex supply chain orchestration activities. Based on the taxonomy above, VLO (the subsidiary) can be seen as a 4PL company, though its parent company, Vos Logistics was founded as a 3PL company and does have its own trucks. Hence, VLO acts as an intermediary company that acquires large (sets of) orders from suppliers and negotiates the allocation of the orders, the terms of transportation (i.e. delivery deadlines, destination) as well as the price at which other carrier companies subcontract these orders.

1.3. Automating multi-party logistics using agents

The focus of this work is on automating, through an agent system the second part of the market interaction, i.e. the daily outsourcing of transportation orders to carrier companies who will actually transport them. The first part, which is actually acquiring these orders from large shippers presents less opportunities for automation through a multi-agent system. The reason is that these contracts are usually fewer, larger and closed over a longer time horizon (e.g. a company based in the US may delegate to Vos Logistics Organizing the delivery of the goods imported into Europe over a period of one year). Such large, complex type of decisions cannot yet be expected to be delegated to software agents.

However, allocation of orders on a daily basis to different 3PL carriers was identified as an area with clear potential to benefit from more automated techniques (our previous AAMAS'06 survey paper (van der Putten et al., 2006) examined this potential). This automation would involve decision support systems for human planners in the first stage, and next some of the decisions could be delegated to software agents.

A final note about how the allocation occurs in current practice: in the Vos case, negotiation over most orders occurs in a small group of companies who are invited to submit bids for different orders as they arrive in the system. In some cases in which no reasonably priced offer is made, Vos may also solicit other outside companies and carriers to submit a bid (this includes multimodal options, such as rail or water transportation carriers). However, these cases are mostly exceptions (they account for less than 20% of the total value of the orders (van der Putten et al., 2006)), so most business is conducted in a group of (up to) 10 companies that can submit bids for a given set of orders. This is the case we are interested in automating through the auction platform presented in this paper.

1.4. Goals of this work

Over the years, several successful agent-based auction platforms have been developed in order to allow comparison and evaluation of automated trading strategies. The Trading Agent Competition is, perhaps, the most well-known example of this (see (Wellman, Greenwald, & Stone, 2007) for an overview) – most related to this work being its supply chain version (Sadeh, Eriksson, Finne, & Janson, 2003). These platforms are, however, simply not suitable for our basic goal, which is to convince the Vos Logistics Organizing management (and their partner carrier companies) that agent-mediated electronic auctions can actually be used in practice to automate their daily outsourcing of transportation orders. For this purpose, a custom-based platform was required, modeled around a business case which the planners that actually perform these operations daily can easily recognize and use.

Since the final system is to be used by logistics planners, such a system should closely resemble a real-world case, and allow its users to identify the bidding and planning decisions to be taken in this platform as decisions they would usually also take in real life. It should have an interactive, intuitive interface and, moreover, it should seamlessly integrate human agents who take planning and bidding decisions with automated agents implementing an algorithmic strategy or heuristic. This point is especially important for acceptance, since during operational adoption of such a system, it is not realistic to expect that a company would immediately delegate all market decisions to a piece of software, without being confident that such decisions closely model those their human planners would make. To summarize, the goals of this project (and corresponding platform) are:

- The overall goal of the project is to demonstrate the feasibility of applying such an auction system in the day-to-day transportation outsourcing activities of Vos Logistics Organizing (VLO), Nijmegen.
- As a more detailed goal, the platform should allow us to illustrate how different mechanism choices, such as allowing flexible pick-up/delivery times or decommitment ('t Hoen et al., 2005) (with or without a penalty) can improve efficiency and participant profits.

From an AI or agent researcher's point of view, the developed system can also form a platform to test different aspects of distributed decision making in logistics auctions, more specifically:

[1] These figures are valid for the 2006/2007 financial year.