Simulation and Visualization of a Market-Based Model for Logistics Management in Transportation

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Abstract
Distributed logistics and transportation is an important and emerging area of application for multi-agent systems, which has recently attracted a lot of research interest. In previous research ([1], [2]) we have proposed and developed novel techniques to deal with some of the challenges and problems in this application domain. In this paper we describe the software system which was built to visualize and demonstrate our multi-agent model.

1. Introduction

A recent development in multi-agent systems research is their application in the logistics of the transportation sector. Transportation is a challenging application area where, due to strong competition, profit margins are typically low. Furthermore, the current practice of centralized solutions is a bottleneck and does not support the flexibility required for incidence management or exploiting new and profitable opportunities. The multi-agent system paradigm can overcome these challenges and offer new opportunities for profit. This can be achieved by developing robust, distributed market mechanisms.

In recent research ([1], [2]), we proposed a model with online, decentralized auctions, where agents bid for cargo to increase profits by exploiting new transportation opportunities that appear in the course of a day. In this context, we proposed and studied the effect of bidding strategies that are novel for such a large scale settings.

In this paper, we present the characteristics of the software prototype built on the the model described in [1] and [2]. Section 2 gives an overview of the main elements of the underlying multi-agent model, while section 3 describes the visualisation applet.

2. The Transportation Model

The world, in our simulation, is represented either as a \(n\) by \(n\) grid, or as a partially connected graph. The graph structure allows us to build more flexible models, which take into account real road networks.

This world is populated by trucks, multiple depots with cargo, and competing companies. The trucks transport cargo picked up at the depots to destinations on the grid. Each truck is coupled with an agent that bids for cargo for its “own” truck. The trucks are owned by one of the companies, where each company aims to maximize the total profits made by its own fleet of trucks.

Loads for pickup prior to delivery by the trucks are locally aggregated at depots. Such an aggregation procedure is for example used by UPS, where cargo is first delivered to one of the nearby distribution centers. Warehousing, where goods from multiple companies are collected for bundled transport, is another, growing example. In general, we model the origin of loads not as randomly distributed but as clustered, depending on population centers and business locations. Thus depots could also be considered abstractions of important population or business centers.

Like most regular mail services (e.g., UPS) and many wholesale suppliers, we employ a model of “next day delivery”. In the simulations, each depot has a number of loads available for transport at the start of the day. Furthermore, new orders can also arrive for transport during the day. The trucks drive round trips in the course of a day. Each individual truck starts from the same initial location each day, to return to this location at the end of it. Multiple round trips on the same day are allowed as long as sufficient time remains to complete each trip the same day. For the purpose of simulation, we set the length of a typical working day to eight hours. We also assume (for simplicity) that the trucks travel with a constant “average” speed.

2.1 The Market Model

Each piece of cargo is sold in a separate Vickrey auction*. Auctions for loads are held in parallel and can

* In this type of auction, the highest bidder wins the contract but pays the second highest price.
continue over several rounds, until all cargo is sold or until no further bids are placed by the agents in a round. After a load is sold, it awaits pickup at its depot and is no longer available for bidding. In the current model, the agents are not allowed to bid on bundles of cargo. Combinatorial auctions were beyond the scope of the original research, because, in complex simulations, this may lead to an intractable problem for each truck agent (around 300 pieces of cargo are sometimes offered in the experiments, yielding an explosion in the number of bundles - for each of which a pick and delivery problem has to be solved). However, this problem forms the object of ongoing research and recent advances in this area show that tractable algorithms for this problem can be found ([3]).

The agents use the following strategy in each bidding round. First, they determine the valuation of each piece of cargo which is offered in an auction. The valuation of an added load is equal to added profit for this load (the amount of money which the truck receives when the load is delivered minus the additional costs associated with the new path). There is however obviously an incentive for a company to avoid competition between its own trucks. As part of its strategy, each company therefore makes a pre-selection that determines which agents are allowed to bid for the company in each auction. In this pre-selection phase, the company compares thevaluations of the company's agents for the available cargo. The agent with the highest valuation (overall) then bids (its valuation) in the proper auction. This auction is then closed for other agents of the same firm. In this manner, we eliminate the possibility that the no. 2 in the auction, who determines the price, is an agent from the same company.

2.2 The Decommitment Option

Decommitment is the action of foregoing a contract for another (superior) offer. In our model, this means allowing a truck agent the possibility to discard a load to which it has committed earlier, in favour of a more favourable one.

Decommitment was the main mechanism studied in our previous research [2]. In that paper we discussed the preconditions for successful decommitment strategy and how this process can be “hidden” inside each company, so it will not affect the company’s reputation with its customers.

Furthermore, we show (by means of experimental results) that this strategy can lead to significant increases in profits, and these increases scale with the size of the operation and uncertainty of future prospects. The reader interested in the details is asked to consult [1] and [2].

3. The Visualization Applet

In this section we discuss the main features of the java applet that was built to allow visualization of our model [4].

Our visualization is comprised of several panels. The main panel presents the structure of the world (i.e. the grid or the road network graph). Two side panels are used to display information about the current truck or depot selected and general information about the world. The main panel shows the underlying grid, as well as the depots and trucks. Loads appear dynamically throughout the simulation, and their pick-up and delivery points are shown with differently colored arrows. The visualization can run in two modes: static (in which the user can manually browse through the turns in a day) and dynamic, in which the appearance of new loads and movements of trucks throughout the day is dynamic (i.e. controlled by a timer).

The most relevant thing to visualize in such a simulation are the routes the trucks take during the day, since this can give an idea of the planning involved. There are 2 types of routes that may be visualized:

• Actual routes taken by the trucks (here the routes taken by individual trucks or by trucks owned by different companies may be highlighted).

• Planned routes for each truck. This last feature, is in our opinion, one of the the most interesting to visualize. This is because the evolution of the planned paths, as new loads appear at different time points, gives an insight of the complexity of planning algorithms used. The planned routes for a truck may change dynamically several times during the day, because plans are continuously expanded to cover the pick-up/delivery of newly won loads.

To summarize, the main objectives we pursued in building our visualization are:

• Present all information on a single graphical interface

• Provide the user with the ability to easily navigate through the simulation, with complete information and intermediate results.

• The information given in the visualization should be palatable: it can be understood without delving in the underlying complex semantics of the model.

To conclude, we believe that the proposed demonstration achieves the above-stated goals and provides a good insight of the fundamental model proposed by our research.

4. References


