Simulation Tool for Multicriteria Auctions in Transportation and Logistics Domain

Egons Lavendelis, Janis Grundspenkis

Abstract: *Agent technologies and multiagent systems start to appear in transportation and logistics domain only recently. The paper proposes an approach of multiagent system and multicriteria auction for decision support in transportation and logistics domain. The multiagent system consists from clients' agents and logistics companies agents which may participate in four known types of auctions which are used with multiple criteria. A client is an auctioneer who is making decision about the best offer of delivering goods. There is also an auction simulation tool implemented using Borland C++ Builder and MS Access database.*
Key words: *Intelligent Agents, Multiagent systems, Auctions, Intermodal Transport Systems, Logistics*

INTRODUCTION

A transportation and logistics domain with many involved companies that are geographically distributed belongs to complex problem domains. The logistics domain is dynamic where logistics goals, companies' capabilities and beliefs are continually changing throughout the planning process. Moreover the logistics domain is an open domain where organizations may enter or leave the system at any time [6]. Different methods and techniques are used for problem solving in transportation and logistics. Analyses of the great number of publications reveals that traditional mathematical modelling and simulation techniques still dominate for searching of solutions, but new approaches start to appear, such as web- and knowledge based systems, intelligent agents for distributed and mobile solutions., etc. [4].

Agent technologies start to penetrate into transportation and logistics domain only recently. Intelligent agents represent organizations within the logistics domain, and model their logistics functions, processes, expertise, and interactions with other organizations. Some agents simulate users involved in traffic; others are means of transport (trucks, trains, planes, ships), or elements of the traffic infrastructure [10]. Multiagent systems offer such useful features as parallelism, robustness and scalability. Multiagent based approaches are well suited for domains, which require the integration and interaction of multiple sources of knowledge, the resolution of interest and goal conflicts or time bound processing of data [8]. Applications of intelligent systems in transportation and logistics cover such problems as multiagent simulation for traffic modelling, decision support systems for letter transportation, logistics planning, sea freight transportation, vehicle dispatching, railway transportation scheduling, and others [3], [2], [4]. Several successful projects have been described, for example, TELETRUCK system [1] and DIAL system [7].

An agent auction is one more technology to use in decision making in transportation and logistics domain. Agents can collect data form their owners (logistics companies and clients) about their needs and make decisions for their owners or even make deals [5].

There are different criteria for decision making in transportation and logistics domain: price is not the only one criterion for evaluating possible options, how to deliver goods, but different clients have different other needs. Therefore it is necessary to make decisions using multiple criteria, but that is not easy for humans. Agent technologies can help humans with this: they can calculate the best options and make deals according to client's needs.

At the same time investigations of different operation modes in multiagent systems in the context of multimodal transportation and logistics problems are not intensive enough. The paper deals with an approach that uses multiagent systems and multicriteria auctions to make decisions in transportation and logistics. This approach is also demonstrated in the prototype of multiagent based simulation tool. The multiagent system consists from clients' agents and logistic companies agents which allow simulating four different types of auctions. These auctions are organized not by only one criterion, but there are up to six different criteria implemented. At the end of the auction the client can make a deal with the winning agent.

EXAMPLE OF THE MULTIMODAL TRANSPORTATION ROUTE

One very significant cargo flow is from Asia to Europe and one way how to deliver goods from Asia to Europe is by using the following supply chain: "Asian Deep Sea Port ↔ Western Europe Deep Sea Port ↔ Baltic and Mediterranean feeder ports ↔ Railway Container Terminals ↔ European Costumers". One example is shown in Figure 1. [5] We will use this chain as an example to show basic concepts of multiagent systems for selecting the best company and route for transporting goods.

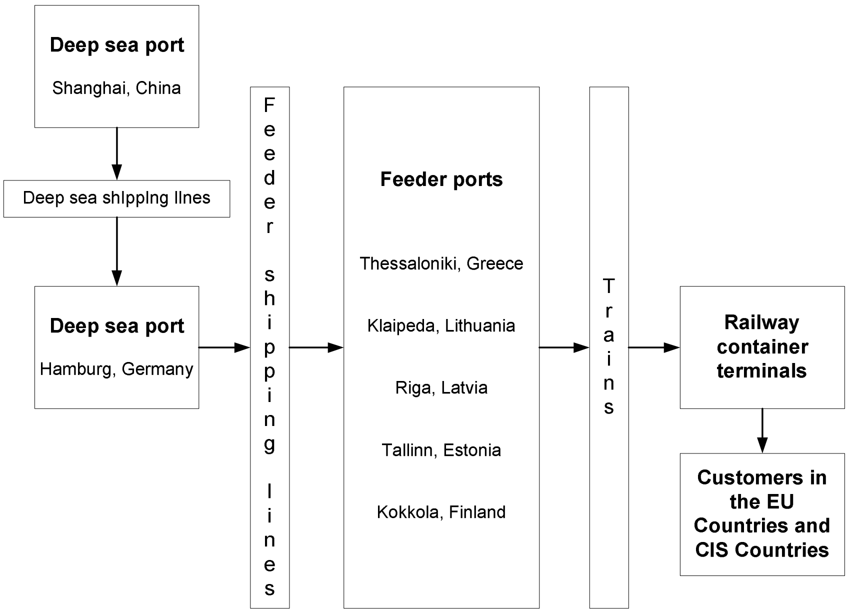

Fig. 1. Example of supply chain

MULTIAGENT SYSTEMS AND AUCTIONS

In this paper we discuss the possibility to simulate cooperation between all interested parties: carriers, clients (owners of goods) and logistics companies. Clients do not directly cooperate with carriers, but through logistics companies. We discuss only communications between clients and logistics companies: they will have agents within multiagent system; it consists of one client's agent (auctioneer in auction) and several logistics companies' agents. [10] Clients agent has information about clients needs and starts an auction according to this information. Then each logistics companies' agent calculates his private valuation: all criterion values in the best possible route which also is calculated using all criteria. Then agent will make a bid according to its strategy in particular type of auction. In this paper we use four different types of auctions [9]:

- English auctions (the most commonly known type of auction) that are first-price, open cry, ascending auctions. The auctioneer starts off by suggesting a reservation price. If no agent (bidder) is willing to bid more than the reservation price, the good is allocated to auctioneer for this amount. In other case, bids are then invited from agents who must bid more than current highest bid, and then the winner is agent who has made the current highest bid. In English auctions dominant strategy is to bid a small amount more than the current price, if it is less than private valuation.
- Dutch auctions are open-cry descending auctions. The auctioneer starts out by offering some artificially high price. The auctioneer then continually lower the current price by

some small value until some agent makes a bid and wins the auction. There is no dominant strategy for Dutch auctions in general.

- First-price sealed-bid auction is an example of one shot auction. There is a single round in which bidders submit to the auctioneer a bid. The winner is an agent that made the highest bid. Agents use the dominant strategy – to bid a bit less than true valuation.
- Vickrey auctions are the most unusual and perhaps counterintuitive of all considered auction types because these auctions are second price sealed-bid auctions. There is a single negotiation round, during which each bidder submits a single bid; bidders do not get to see the bids made by other agents. The winner is an agent who made the highest bid, however he pays the price of the second highest bid. Agents use the dominant strategy – to bid his true valuation. This is the main advantage of this protocol for the auctioneer.

CRITERIA FOR DECISION MAKING

Traditionally auctions are made using only one description of a bid: the price. But in transportation there are many criteria to take into consideration in different cases. These criteria are of different nature and therefore need different approaches. In this paper we will use the following classification:

- Criteria can be characteristics of route or logistics company. The first ones vary in different routes of the same company, the second ones – do not.
- Logistics companies' characteristics can be objective or subjective. Objective criteria are facts about the company and are known for everybody, but subjective criteria are known only by clients (usually from previous experience).
- There are criteria that have their natural measurements (price, time), but there are also such criteria which do not (staff qualification).
- Criteria can have discrete, continuous or Boolean scale.

These different criterion classes also need different approach during the auctions; these differences will be discussed in next chapter.

MULTICRITERIA AUCTION

Multicriteria auction is an auction which uses multiple criteria for bid evaluation. It is done by calculating some evaluation from all criteria. For this purpose it is also needed that user inputs weights for each criterion. Then each bid can be evaluated using equation 1.

$$V = \sum_{i=1}^{n} w_i * v_i \quad \text{, where} \qquad (1)$$

V – evaluation; n – criterion count;
w_i – i^{th} weight; v_i – i^{th} criterion value.

To use equation 1 it is necessary not only to receive weights from user, but also all criterion values from a bidder. But not all criteria are known for an agent: it does not know subjective ones. Thus, bidder includes in its bid only known part of value, but auctioneer adds unknown (to bidder) one. Considering that known criteria are the first ones, known and unknown parts can be calculated using equations 2 and 3.

$$V_{kn} = \sum_{i=1}^{n_{kn}} w_i * v_i \qquad (2)$$

$$V_{unkn} = \sum_{i=n_k+1}^{n} w_i * v_i \quad \text{, where} \qquad (3)$$

V_{kn} – known part of evaluation; V_{unkn} – unknown part of evaluation;
n_k – criterion count for known part; n – total criterion count;
w_i – i^{th} weight.

Next question is how bidders can calculate how much to bid. Agent needs some input form an auctioneer. In sealed-bid auctions bidders need to know only starting point destination and weights – bidders do not receive any information about other bids.

It is different in open-cry auctions: agents need to know the best offer to overbid it, but it will calculate only the known part. That means its input must be the needed known part. It can be calculated using equation 4.

$$In = V^{max} - V_{unkn} \text{, where} \quad (4)$$

In – agents input; V^{max} – maximal bid; V_{unkn} – needed unknown part.

When agent receives its input, the first thing it does is to calculate his private evaluation of it. It can be done interpreting terminals and routes between them as a graph and use search algorithms [5]. Then if an agent decides to make a bid according to its strategy, it needs to calculate what price to include in a bid to have the bid with wanted evaluation. Assuming that price is the first criterion, it can be done using equation 5.

$$v_1 = \frac{V_{kn}^{bid} - \sum_{i=2}^{n_k} w_i * v_i}{w_1} \text{, where} \quad (5)$$

v_1 – first criterion (price); V_{kn}^{bid} – known part for wanted bid;
n_k – criterion count for known part; w_i – i^{th} weight;
v_i – i^{th} criterion value; w_1 – weight for price.

This method states one limitation: the weight for price is not 0 – auction can not be without price as criterion. But this limit is also logical: price is the only one criterion that bidder can freely change. If there will be no criteria to change, it will not be possible for bidders to bid what they want and therefore auction to take place.

Equations 1 till 5 are needed to migrate from single criterion auction to multicriteria one. The other consideration is users view. How can user who usually is a businessman determine what weights to use? One possible solution is to state that weight for price is 1. Then all other weights will be prices per unit of this criterion. And this language is well understood by business people. That means user has to enter only weights (prices per unit of criterion) and starting values of criteria (only in open-cry auctions). This solution is used in the implemented simulation tool.

DEVELOPED SIMULATION TOOL FOR MULTICRITERIA AUCTION

The first thing to do to implement this tool is to choose some criteria to implement. Real life problem can have 20-30 or even more criteria, but for simulation tool the main thing is to include all kinds of criteria (both route criteria and logistics companies' criteria, both objective and subjective criteria, etc.). Table 1 shows selected criteria for implementation and their characteristics.

Table 1. Selected criteria

N	Criterion	Origin	Objectivity	Measurement units	Scale
1	Price	Route		Natural (money units)	Continuous
2	Total delivery time	Route		Natural (hours)	Continuous
3	Cargo safety	Route		Natural (%)	Continuous
4	Monitoring possibility	Company's	Objective	Natural (Yes/No)	Boolean
5	Reliability	Company's	Subjective	Artificial (0-10)	Discrete
6	Staff qualification	Company's	Subjective	Artificial (0-10)	Discrete

These criteria are used to make evaluation in the simulation tool which is implemented using Borland C++ Builder and MS Access database. The simulation tool only shows the mechanism how these auctions can be carried out. At the moment there are big differences from real deal making system. First, our system runs on one computer and it is not possible to connect to it through Internet. Second, our system has common database for agents. Agents get from it only their knowledge defined by relationships in this database. At the same time, it is needed to stress that these differences are only technical realization details, and they do not affect the auction algorithms and ideas. That is only a matter of programming client server applications to implement a real system.

User has to input weights and starting values for each criterion into auction parameter form to start an auction by pressing button "Star Auction" and get every next bid by pressing "Next bid". Tool's main window with first bid for route Shanghai - Liepaja is shown in figure 2. It also supports knowledge base editing in simple database editing forms: user can edit all possible lists (logistics companies, schedule, etc). This part is shown in the right part of figure 2 (buttons are disabled during the auction). All forms are not shown.

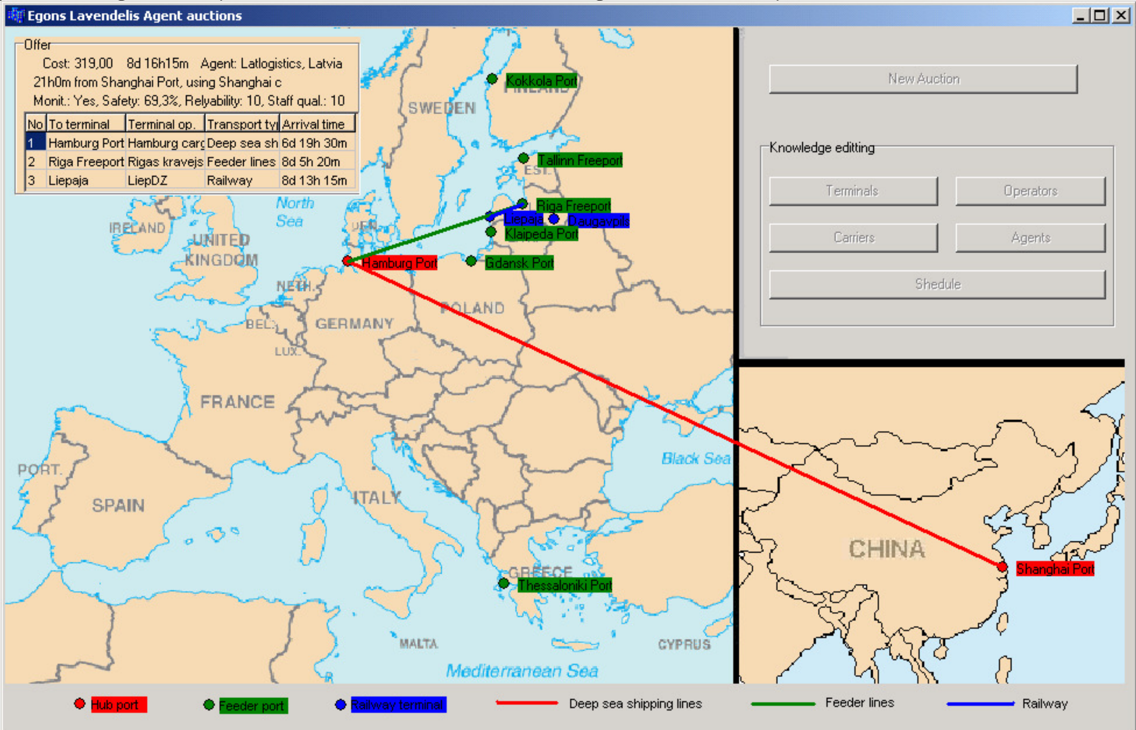

Figure 3. Bid visualisation

CONCLUSIONS AND FUTURE WORK

The developed simulation tool demonstrates that it is quite simple to implement a multiagent system for automation of communication between clients and logistics companies. The deal may be made using different types of auctions; these auctions can be multicriteria auctions, what means that it is possible to find the best way to deliver goods for clients not only by price but also by other criteria. That minimizes efforts for finding the best way to deliver some goods: the client instead of contacting all known logistic companies and making complex multicriteria decisions can just enter his wills and in few moments get deal with one company. Logistic companies, in their turn, need not to make negotiations with all clients, they can just announce their company's politics to corresponding agents and these agents will make deals with possible clients.

There is no significant difference between implementing one criterion auction or multicriteria one. Multicriteria auction just involves some extra calculations, but they are not too complicated. From users viewpoint the changes are a bit more significant: first of all, user can find best offer by multiple criteria, the second one, user has to enter more input data, but this input is maximally simplified. The third is that user gets more data about the offer: all criterion values. And also it is worth mentioning that user may get confused if current offer get more expensive than the previous one: it is because other criteria have better values and total evaluation is therefore better.

It is possible to include in this system also carriers and automate their communication with logistic companies. This is one of the directions of future work. Then it will be a multi-multi-agent system and each logistic company and carriers with which it cooperates make a holon. For client this holon is represented by a logistic companies agent.

Multiagent system is advanced and quite cheap solution for communication problem solving between logistic company and their clients, and also carriers.

The future work is to make our systems more realistic. There are no big difficulties to implement a real deal making system. That is only a matter of programming of client server mechanisms, because all complicated algorithms are already implemented in the developed simulation tool. It is also possible to make these auctions a legal instrument by using electronic signatures. In this case all deals should be made online and a lot of human resources should be saved.

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ABOUT THE AUTHORS

Assistant researcher Egons Lavendelis, B. Sc.ing, Department of Systems Theory and Design, Riga Technical University, Phone: +371 29876891, E-mail: egolav@inbox.lv.

Prof. Janis Grundspenkis, Dr. Habil. Sc.ing., Department of Systems Theory and Design, Riga Technical University, Phone: +371 7089581, e-mail: jgrun@cs.rtu.lv.