Auction Model of P2P Interaction in Multi-Agent Software

Anton Ivaschenko[1] and Andrey Lednev[2]
[1]Magenta Technology, 68, Lombard Street, City of London, EC3V 9LJ, London, U.K.
[2]Samara State Technical University, Molodogvardeiskaya street, 244, Samara, Russian Federation

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Abstract: The paper describes one of the possible models of interaction management of active software agents in P2P network of the enterprise information space. The matrix form of enterprise management is being projected on the P2P network of interacting software components. It is proposed to study the problem of resource allocation using Auction model enhanced by the opportunity of its management by changing dynamical characteristics. The approach shows that the introduction of delays and accelerations allows to increase the efficiency of solving scheduling problems.

1 INTRODUCTION

Modern trends in the area of enterprise management consider various organizational models. For example, a matrix model is actively used nowadays to represent the processes of collaborative decision making according to coordinated staff interaction. Integrated information space is required to support such structures in order to automate decision making processes.

Network architectures of bundled interacting software solutions should be created to form such an environment. The concept of building a distributed heterogeneous integrated information space with P2P networks (Schoder and Fischbach, 2003) of software agents capable of interaction by means of messages' exchange (Lednev, 2010) becomes widely spread.

The principles of bio-inspiration (Leitao, 2009) are theoretically used for solving design problems of such information environments that allow considering users and software agents as a complex evolving system. In practice this concept is being successfully applied in implementation of multi-agent technologies (Andreev and Glashchenko, 2009).

However the questions of organizing the management in such systems are still open. The reasons of it are: an impossibility to apply direct instructions, an infeasibility of classical optimization and a whole complexity of virtual multi-agent world.

One of the most perspective approaches to deal with these problems is to provide indirect informational management enhanced by methods and means that are focused on a rhythmicity analysis of messages' exchange between the interacting participants: enterprise employees and software agents as their representatives.

In this paper we present an opinion on how to organize such an interaction in a form of auction. Such approach can be helpful for development of intellectual automated resources scheduling systems in different problem domains, for example in transportation logistics.

2 AUCTION BASED INTERACTION IN INTELLIGENT SCHEDULING

One of the most widespread areas of multi-agent technology application is real time scheduling of mobile resources in transportation logistics. Real-time mode means an ability to incrementally schedule the orders that arrive at various times providing the minimal deviation from delivery time with the maximal load of transport (to reduce backhaul run).

Driver involvement in decision making will be very helpful for finding appropriate solutions as it will allow considering specific order requirements. In response to such individual approach dispatcher expects the growth of overall service quality. Thus

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dispatcher is “selling” orders to drivers inspiring them to provide better service.

Described interaction can be technically organized with modern info communicational technologies. In order to automate the solution when driver requirements are known preliminary a negotiation process can be simulated in the virtual environment organized in the form of P2P network of software agents that represent decision-makers. Resource distribution in the described environment can be organized on the basis of auction model. According to this model the order can be treated as a lot, dispatcher as an auctioneer and drivers as bidders. The strategic aim of this auction is to maximize the load of resources that increases the risks of fail to serve the order and make the whole schedule inconsistent.

Auction can be defined as a public sell of one lot according to the predefined rules. The auctioneer or the Centre (the agent that represents a centralized dispatcher) at different moments of time exposes lots (orders), which are of different level of interest to the bidders (drivers or their agents). The winner of the auction is an agent who buys a lot according to the rules. The aim of an agent is to win as much lots as possible that are of a particular interest for him at minimal prices.

The proposed auction is divided into an uncertain number of iterations. Blind bids are made during the iterations, and the Centre announces the highest bid afterwards. The Centre announces the price for new iteration and the approximate duration of the following iteration. In response any of the participants can increase the bid and thus initiate a new iteration. Auction is finished when no new bids are made during the iteration.

In real auction auctioneer makes pauses between gavel heats to stimulate making higher bids faster. The same way in multi-agent information space the Centre activates interaction between software components by setting up the timeframes of iterations. Therefore the Centre provides indirect information management.

So the following 2 ideas can be proposed to provide information management of multi-agent intelligent scheduling:

1) implement the auction model for organization of effective resource allocation in P2P distributed information space;
2) manage agents’ negotiations in a process of auction based resources allocation by varying time intervals of the bidding iterations.

The difference of P2P auction from an ordinary multi-agent auction is that the Center as P2P node addresses each bidder individually that allows implementing a method of agent’s adaptive management by information. This method is based on adaptive limiting, scoping and garbling being applied to each node individually. For example, a taxi dispatcher can inform different drivers only about filtered orders to provide better cabs geographical distribution and higher service level.

3 AN AUCTION MODEL FOR AGENTS’ INTERACTION

In the following section the formal model of the proposed approach is presented. For this purpose the following variables are introduced:

- C_0 is an initial price of a lot;
- v_i, $i = 1...N$ is a value of a lot for every particular agent (N is agents’ total number);
- $c_{i,j}$ is a price of the bid made by an actor;
- $j = 1...M$ is a number of iteration;
- Δt_j is an iteration’s duration.

The durations of iterations are not equal, as well as not fixed, since they are started by new price announcements made by the Center. New lot price $C_{i,j}$ is chosen as a maximum between all bids.

Auction is finished after the following time passes since its start:

$$T_A = \sum_{j=1}^{M} \Delta t_j \quad (1)$$

At each iteration the Centre is interacting with agents using P2P principle: every message contains a new bid proposal of lot price at the moment $t_{i,j}$:

$$s_{i,j} = \{C_{i,j}, t_{i,j}\} \quad (2)$$

Response messages can be sent by agents in turn:

$$b_{i,j} = \{c_{i,j}, t'_{i,j}\} \quad (3)$$

where $c_{i,j} = C_{i,j} + \Delta c_{i,j}$.

Time required for an agent to make a decision is $t'_{i,j} - t_{i,j}$.

In such a model some agents can miss iteration and make no bids. The goal of the Centre that organizes $k = 1..K$ auctions can be defined as:

$$\sum_{k=1}^{K} \max_i C_{i,M} \to \max, \sum_{k=1}^{K} T_{A,k} \to \min \quad (4)$$

The goal of an agent is the following:

$$\sum_{k=1}^{K} v_{i,k} \cdot \theta\left(c_{i,M,k} - \max_i C_{i,M,k}\right) \rightarrow \max,$$
$$\sum_{k=1}^{K} c_{i,M,k} \cdot \theta\left(c_{i,M,k} - \max_i C_{i,M,k}\right) \rightarrow \min \tag{5}$$

where $\theta(x) = \begin{cases} 0, x < 0; \\ 1, x \geq 0. \end{cases}$ is step function.

This means that an agent can be satisfied by buying lots at minimal price, and it doesn't matter what time it takes. The Centre to achieve its own goal in turn can change the durations of iterations and the number of actors involved (deciding whom and when to send the messages $s_{i,j}$).

In order to sell a lot at its highest price the Centre needs to organize a competition between the agents, which requires a proposal request strategy (plan). Every agent can manage the size and time of its own bid thus arising interest to itself from the Centre. On contrary to achieve equilibrium the Centre should announce its plan to the agents. In this case it is possible to study the dependence between the plan of the Centre and the strategies of agents.

As an example of the proposed interaction model implementation in practice the following resources allocation problem can be considered. Nowadays many shops practice separation of sales to several stages. At every next stage the price of the good is decreased. Thus shop tries to get rid of out-of-date things and renew the assortment getting as max profit as possible.

On the other hand buyers want to buy the goods they need at the lowest price. Still a customer can't be confident what time to wait for a sell-out: somebody else can be ahead or the shop can stop "the game". A shop can also fix the price thus making the wait of a customer senseless. This can be simulated by a model of simultaneous numerous auctions in several iterations with a single Centre and unknown number of agents.

The problem statement can be simplified by depriving the agents to affect the price of a lot. In this case the time factor becomes determinative. It should be mentioned that constant price change of the bid can't affect the resulting lot price. In case when actors represent no interest (make no bids) the Centre is forced to lower prices faster.

4 SIMULATION

To study the proposed approach some simulation modeling was performed aimed to identify the opportunity of increasing resulting lot price by managing iteration time. Simulation included two experiments in real time with different durability of lot sale. In order to carry out the experiments a special software environment was implemented in J2EE modeling auction based interaction of agents in distributed information space.

The Centre specified the time after which the agents had to make bids. Among the proposed bids the highest one was chosen as the price of the lot for the next iteration. The size of the bid made by an agent was calculated randomly using normal distribution against the current price of the lot. Neither the Centre nor the agents knew the time when auction would be finished.

Figures 1 – 3 illustrate the results for 2 agents' auction. In the first case (without time management) iteration's duration was constant: 41% of lots were sold within 3 iterations and other 59% within 4. In the second case (see Figure 2) The Centre was enabled to manage iterations duration (see Figure 3).

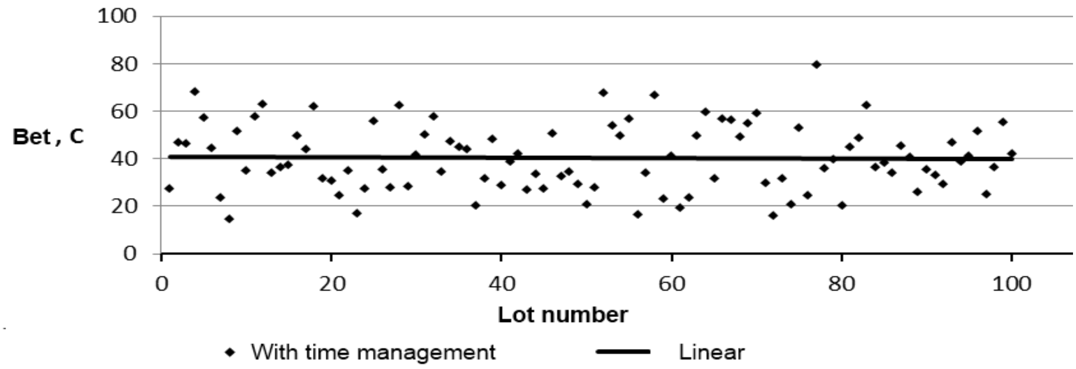

Figure 1: Bids during iterations without time management.

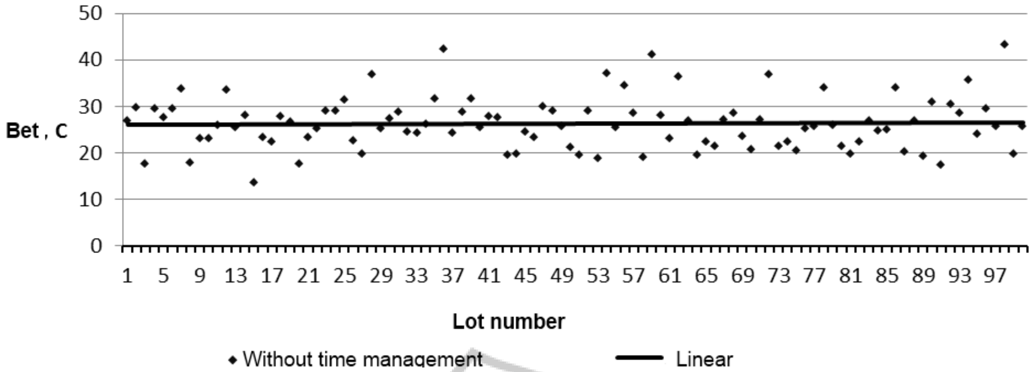

Figure 2: Bids during iterations with time management.

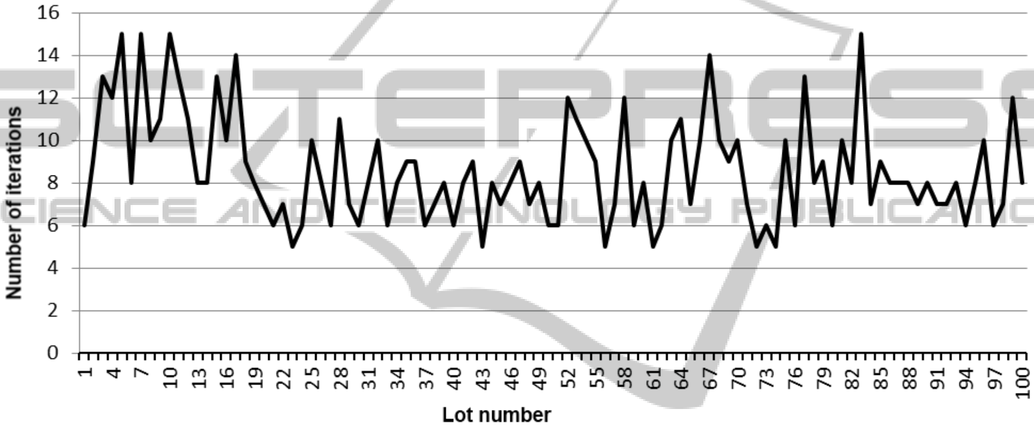

Figure 3: Number of iterations in experiments with time management.

So it reduced the time of iterations proportionally the sizes of the bids: the higher was the bid the shorter was the following iteration. As the result approximately from 5 to 15 iterations were made while the lot was played.

The difference between lot prices appear in both cases, which can be explained by the normal distribution of bid prices. However in general the simulation results proved the idea that the final price of the lot is be higher if it is played within more iterations.

5 CONCLUSIONS

The proposed approach and a model for auction based interaction of agents in integrated information space allow implementation of multi-agent software for P2P networks management. They expound the ideas of indirect management by information that corresponds with the concepts of bio-inspired approach and can be extended by the methods of conditional management.

The results of simple simulation prove the possibility to use auction models in solving practical problems of intelligent scheduling, for example in transportation logistics, and can be helpful for automated decision making support in real time.

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