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Negotiation strategies of programmable agents in Continuous Double Auctions

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Chapter 1

Introduction

Auctions as a method of selling and buying goods have a long history, initially there were only ascending auctions with simple rules (now known as English auctions) but with time a variety of types of auctions has emerged. Now, auctions have become a very popular method of trading popularized by on-line auctions as Ebay or Allegro (a big Polish auction platform).

According to definition made by McAfee and McMillan in 1987: "an auction is a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants".

A special type of auctions, maybe not the most popular in an on-line internet auctions but interesting from point of view of computer simulation, are so called *double auctions*. In double auctions, there are multiple buyers and sellers on the market that place their offer simultaneously.

In this work we review strategies of agents participating in a double auction. There are a lot of different categories of strategies: some consider history, others are reacting on the last placed bid or apply learning algorithms. Some strategies, as ZI, GD, and AA, have been already reviewed in an earlier publication of the present authors [21]. They are repeated here to make a possibly full compendium of strategies proposed in the literature.

The practical context of this research is the double auction for trading emissions of pollutants. Emission, in this context, is the short name for "permission to emit a unit of greenhouse gas"; its unit is either one tonne of carbon dioxide or the mass of another greenhouse gas which is recalculated to so-called carbon dioxide equivalent (tCO2e) emissions. This is expressed in units like Certified Emission Reductions (CERs) or carbon credits. This concept was introduced in the Kyoto Protocol, which entered into force in

16 February 2005, obliging countries that ratified it to limit their greenhouse gases (GHG) emissions below the levels of 1990.

The protocol introduced so called "flexible" market-based mechanisms (Emission Trading, Joint Implementation and Clean Development), which are meant to achieve the common reduction target with minimal costs, without knowledge of the parties cost functions. The emission trading market is still not mature and it is still under the process of adjusting the rules and protocols to make it efficient and resistant to collapsing. The Chicago Climate Exchange market ceased operations in 2010 because the legislation was refused by the US Senate and companies were no longer interested in trading this commodity.

There are different schemes developed for this type of market. In report [26], the English auction trading scheme for emission permit trading was considered. In the present work the double auction mechanism for emission trading is defined, as it is a very popular method of creating efficient markets.

This work summarizes the most well known strategies, that present the evolution of automated negotiation strategies: from simple and intuitive approaches as ZI, PS and ZIP, to more forecasting like GD and adapting as AA strategy. None of the general issues of on-line auctions are discussed here. An interested reader is referred to recent reviews of these matters [12, 17, 24].

The structure of the paper is as follows. In chapter 2 the current state of research on the Continuous Double Auction, emission trading and agent strategies are shortly reviewed. In the following chapter the concept of negotiations and different ways of trading is described. In chapter 4 some informations on double auction are presented. Chapter 5 discusses the formal model of the auction double market used in this paper. The following chapters contain the description of the existing strategies for participants in the continuous double auction, they are divided to strategies using only current information, GD strategies, AA strategies and FL-strategy, that uses fuzzy rules to determine the value of next shout. The general architecture of the implemented software is located in the chapter 10, followed by description of its implementation. In chapter 11 some preliminary results are presented. Conclusions summarizes the whole report. Also future works are sketched there.

Chapter 5

Model of the market

5.1 Market mechanism

The market allows only registered agents to trade, they are called **participants** in the market. It is assumed that if the participant entered the market it is trustworthy and has enough funds to pay for the commodity.

Each participant places an offer on a market, the offer has to include:

- participant data,
- type of the deal, marking if the offer is for selling a commodity (an ask) or for buying a commodity (a bid),
- price that is offered for the unit.

The Continuous Double Auction defined in this paper is a symmetric auction, where the number of buyers and sellers is unlimited. A participant intending to buy a unit of a commodity (i.e. a buyer) places an offer on the market; the offer is a *bid* and includes the price that the buyer is willing to pay for the commodity. A participant intending to sell a unit of a commodity (i.e. a seller) places an offer on the market; now the offer is an *ask*, which includes the price the seller wants. An *outstanding bid* is a bid with highest offered price in this market session[1], for which no seller has been found. Similarly, an *outstanding ask* is an ask with lowest price in this market session, for which no buyer has been found. Each agent has a limit price λ_i: for a seller

[1] A market session is a period of time when participants can place bids, often the session lasts a day.

it is the lowest value the seller is willing to get for the unit of commodity; for a buyer it is the highest value the buyer is willing to give for the unit of commodity.

The market clears whenever a placed offer can be matched to one of those already existing on the market. In other words: when the price of a bid is equal or greater than the price of the ask. The paired offers are removed from the market, and all other offers remain unchanged.

At any given time, there can only be at most one offer of each participant on the market. A participant that sends a new offer is basically updating its existing offer. Participants decide how the price of the offer is modified: each of them can increase or lower it regardless of the type of agent. There is defined a minimal price change value (the price step), but no maximum or minimum prices are specified. There is no possibility to place an offer without the price specified.

Bids and asks sent to the market are public information accessible to each agent; the data of the transactions are also published.

5.2 Model

Description of symbols

M – symbol describing the market,

g – a commodity that is auctioned off,

b_j – symbol describing an i-th buyer in the market,

$B = (b_1, \dots, b_{nb})$ – finite set of buyers in the market,

s_j – symbol describing an i-th seller in the market,

$S = (s_1, \dots, s_{ns})$ – finite set of sellers in the market,

t_k – time period k on a market,

$p(t_k)$ – current market price of the commodity, it corresponds to the price of most recent transaction,

$bid(t_k)$ outstanding bid at a time t_k (in short also $b(t_k)$),

$ask(t_k)$ outstanding ask at a time t_k (in short also $a(t_k)$),

Concepts specific for an agent

id_i – identifier of the agent i, takes two values: s for seller or b for buyer,

$n_i(t_k)$ – number of the items that the agent i wants to buy or sell,

$\lambda_i = (\lambda_{1,i}, \ldots, \lambda_{n_i(t_k),i})$ – vector of the limit prices of the units of the commodities that are to be sold or purchased by the agent i, in our case $\lambda_{n_i(t_k),i} = 1$, so λ_i is a scalar,

$bid_i(t_k)$ – bid of the agent i on a market at the time t_k (in short also $b_i(t_k)$),

$ask_i(t_k)$ – ask of the agent i on a market at the time t_k (in short also $a_i(t_k)$),

$budget_i(t_k)$ the budget of the agent i at the time t_k,

$comp_i(t_k)$ – computational resources (memory and processing power) available to agent i,

A_i – set of possible actions for agent i,

Str_i – strategy for i-th agent.

The market state at time t_k is described as follows:

$$st_M(t_k) =< g, B, S, p(t_k), bid(t_k), ask(t_k) > \qquad (5.1)$$

The state of the agent i at time t_k is described as follows:

$$st_i(t_k) =< id_i, n_i(t_k), \lambda_i, budget_i(t_k), comp_i(t_k) > \qquad (5.2)$$

The set of actions for buyer is: $A_i =< bid, silent >$ and respectively for seller: $A_i =< ask, silent >$.

In [35] the strategy was defined as follows: for agent $i \in I$, its strategy Str_i defines a mapping Γ_i from the history of the agent state $H(st_i(t_{k-1}))$ and the market states $H(st_M(t_{k-1}))$, and the current agent state $st_i(t_k)$ and the market state $st_M(t_k)$ to a set of atomic actions $SA_i = \{a_1^i, a_2^i, a_3^i, \ldots, a_k^i, \ldots\}$, $a_k^i \in A_i$, where A_i is the set of all possible actions for the agent i at time t_k.

The state of the market changes with every bid or ask sent by the agents, so t_k is incremented with every new offer. The market state transition is defined as:

$$st_M(t_{k+1}) = T(st_M(t_k), H(st_M(t_{k-1})), SA_i) \qquad (5.3)$$

$T(.)$ is a transition function that depends on the current offer placed on the market. If the offer is a bid ($SA_i = bid$) then it is checked if there is an offer of that participant on the market. If the answer is positive, the offer is updated, otherwise the new bid is inserted, bid becomes $bid_i(t_k)$. If there is a matching offer, the transaction occurs, parties pay the price that is: $p(t_k) = ask(t_k) + |\frac{bid_i(t_k)-ask(t_k)}{2}|$ (for the offer that is an ask the price is: $p(t_k) = ask_i(t_k) + |\frac{bid(t_k)-ask_i(t_k)}{2}|$). The outstanding bids are updated to new values chosen from the offers that remain on the market. If the deal cannot be made, but the new bid brings a higher price than the current outstanding bid the value of the $bid(t_k)$ is updated. If the new bid is lower than the outstanding bid the offer is added to the list of offers (or it updates the already existing offer of the same agent).

If the offer is an ask, the procedure is similar to the previously described. A change in the market depends on whether there is a matching bid in the market and whether the price of the new ask is lower than the outstanding ask.

If an agent chooses the action *silent*, then it is checked if the deadline for inactivity has not passed. If it did, then the auction ends. An auction can also end after a fixed number of time units.

The match between the ask and the bid also changes the state of the agent. The number of units to sell and to buy is decreased by one[2]: $n_i(t_{k+1}) = n_i(t_k) - 1$ and the budget is decreased: $budget_i(t_{k+1}) = budget_i(t_k) - p(t_{k+1})$.

Participant's individual goal Each of the participants takes part in the auction because it assumes that it can make a profit. It is assumed that participants act rationally and maximise their own profit functions. The goal of the buyer agent is to purchase the required amount of commodity in the current session, he is limited by the available budget and none of the bid can be made with price higher than the limit price. For seller the goal is to sell all units of commodity that he has to offer in current session, with constraint of not asking lower price than the limit price.

[2] This auction scheme is single-unit, with multi-unit auction this value has to be defined differently.

Chapter 12

Conclusions

Emission permits are a new commodity that can have a very uncertain volume. Moreover, uncertainties for different types of greenhouse gases differ considerably. For example, uncertainty of emission of CO_2 from a power plant may be few percents, while that of N_2O from agricultural activities may be close to 100%. Thus, a risk for traders to realy reach the imposed emission level is much different when buing one or another emissions. Trading under such conditions requires new rules, but also provides a unique base to develop new strategies that are able to fulfill the requirements. Before it will be possible to include uncertainties in the agents behavior, the market scheme has to be designed and tested.

Given the tool as the *multi-agent system*, it is possible to design a market that is be simple, dynamic and that allows participants to adjust their desired profit and the time of placing an offer. The continuous double auction chosen in the report has simple rules and does not impose limitations on neither the number of participants nor their strategies.

The aim of the present report is to go through the most well-known strategies for this type of market, to classify them and to summarize their properties. The existing strategies can be divided into few groups: simple and reactive strategies (e.g. TT, ZI, ZIP); strategies that are using historical data to predict the prices (e.g. GD) and strategies that are exploiting features of agents and market configuration (e.g. Kaplan, AA). Most of the strategies (except for the very simple ones) result in the market price converging to equilibrium price and generally in most participants reaching profit.

The next step is to create agents that will dynamically adjust or even change their strategies depending on the situation on the market. After that, specific features of the emission market will be added to check how agents behave. Limit price will become a function of traded permits and participants would have to consider the level of uncertainty of the traded permit.

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