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Negotiation strategies of programmable agents in Continuous Double Auctions

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Contents

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 7

GD strategies

7.1 Belief functions

GG strategy has been proposed by Gjerstad and Dickhaut in 1998, [9]. Formation of price in GD strategy relies on so called *belief function*. A belief function is a subjective estimate of probability for an ask or a bid to be accepted. To construct a belief function a history H of earlier market activity data is considered. Old orders are, however, of smaller importance. Thus, not full history H is used in formation of an order price, but only some recent activity, i.e. a vector of orders leading up to last L transactions, denoted by H_L. The parameter L is the memory length of traders. The invalid orders, like those which do not obey the spread reduction rule, may be ignored in the history. It is also assumed that traders have only information on transactions done in the past, i.e. the accepted shouts, as well as to the rejected shouts, gathered in the history H_L. A belief function f is then of a form $f(H_L, p)$, where p is the order price.

A simple statistic for estimating the probability $\pi(a)$ of acceptance of an ask a for a seller would be the frequency

$$\pi(a) = \frac{TAG(a)}{AG(a)}$$

where $TAG(a)$ is the number of accepted asks in the history H_L with prices $p \geq a$, and $AG(a)$ is the number of all asks in the history H_L with prices $p \geq a$.

Similarly, estimated probability $\kappa(b)$ of acceptance of a bid b for a buyer could be the frequency

$$\kappa(b) = \frac{TBL(b)}{BL(b)}$$

where $TBL(b)$ is the number of accepted bids in the history H_L with prices $p \leq b$, and $BL(b)$ is the number of all bids in the history H_L with prices $p \leq b$.

Let us notice that it is reasonable to define these frequencies only at those points, in which an offer exists in the history H_L. Between these points the functions would be constant, right continuous for sellers and left continuous for buyers. This would be a rather low accuracy approximation of frequencies at points missing in the history H_L.

The number of points in the history H_L used to calculate above estimates $p(a)$ and $q(b)$ is rather small. But it can be increased by simple heuristic reasoning. For a seller, having in the history a bid b with the price greater or equal to the price of an ask a means that this ask would be accepted. Thus, all bids in the history with prices greater than the price of a can be treated as accepted asks. Moreover, if an ask in the history with the price a' smaller than the price a was not accepted, it means that the bid a and all bids with higher prices would not be accepted. Taking into account this reasoning, Gjerstad and Dickhaut [9] modified the above statistics to form the belief functions.

Then, the belief function for a seller is defined as

$$f_s(H_L, a) = \pi(a) = \frac{TAG(a) + BG(a)}{TAG(a) + BG(a) + RAL(a)} \tag{7.1}$$

where $BG(a)$ is the number of bids in the history H_L with prices $p \geq a$, and $RAL(a)$ is the number of rejected asks in the history H_L with prices $p \leq a$.

Similarly, a belief function for a buyer is defined as

$$f_b(H_L, b) = \kappa(b) = \frac{TBLb + AL(b)}{TBLb + ALb + RGB(b)} \tag{7.2}$$

where $AL(b)$ is the number of asks in the history H_L with prices $p \leq b$, and $RGB(b)$ is the number of rejected bids in the history H_L with prices $p \geq b$.

The above expressions define the values at the prices which exist in the history H_L. The values of the belief function for other prices are obtained by an approximation. Gjerstad and Dickhaut [9] proposed to use the cubic spline approximation.

7.2 Price formation

To set the shout price, a trader maximizes subjective expected surplus in the space of valid orders. The subjective expected surplus for an order $o = \{a, b\}$ is defined as

$$E_a = -\pi(a)\mu \qquad \text{for a seller}$$

$$E_b = \kappa(b)\mu \qquad \text{for a buyer}$$

When the spread reduction rule is adopted, the maximization takes place on the interval $I = [b_{\max}, a_{\min}]$, where $b_{\max}$ is a current highest unaccepted bid and $a_{\min}$ is a current lowest unaccepted ask. Then, the value of a shout is calculated from the following maximization

$$\max_{o \in I} E_o \tag{7.3}$$

with $o = a$ for a seller, and $o = b$ for a buyer.

The full price formation procedure is repeated, including calculation of a current belief function, for consecutive values of t. The traders shout, if the calculated order is valid. However, the index t is dropped in the above derivations to simplify the expressions.

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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