61/2012

Raport Badawczy
Research Report

RB/33/2012

Negotiation strategies of programmable agents in Continuous Double Auctions

Z. Nahorski, W. Radziszewska

Instytut Badań Systemowych
Polska Akademia Nauk

Systems Research Institute
Polish Academy of Sciences

POLSKA AKADEMIA NAUK

Instytut Badań Systemowych

ul. Newelska 6

01-447 Warszawa

tel.: (+48) (22) 3810100

fax: (+48) (22) 3810105

Kierownik Zakładu zgłaszający pracę:
Prof. zw. dr hab. inż. Zbigniew Nahorski

Warszawa 2012

SYSTEMS RESEARCH INSTITUTE
POLISH ACADEMY OF SCIENCES

Zbigniew Nahorski, Weronika Radziszewska

Negotiation strategies of programmable agents in Continuous Double Auction

Warszawa 2012

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 4

Continuous double auction

The CDA is considered in this report in a market for a homogeneous good. There exist many different CDA models. For example, orders can be given for multiple or single units. Unaccepted orders can be remembered or replaced by more favorable ones. However, we do not discuss mechanisms of a market here and focus rather on negotiation strategies.

We start with introducing some basic notions and notations. We assume that a trader i (in our case a programmable agent) has a private secret *limit price* λ_i for buying or selling. For a seller it is the lowest price, below which it must not sell. For a buyer it is the highest price, above which it must not buy. This limit price may depend on the number of units bought or sold. The extension is quite straightforward, by making the limit dependent on the number of units. This will be not introduced here in order to simplify notations.

If a trader maintains to complete transactions at a better price, higher than λ_i for a buyer or lower for a seller, then he generates a profit at a discrete time t denoted by $|p_i(t) - \lambda_i|$, where $p_i(t)$ is the current price. Time t is connected with numbering in the sequence of announced orders. Just, each shout increments time t by 1. The aim of a trader is to maximize the profit over all trades. Following the works of Vernon Smith [29] in experimental examination of markets with double auctions, with human traders, the performance of a trader is measured in terms of *efficiency*, which is the total profit of the trader divided by the maximum theoretical profit possible to obtain by that trader, that is the profit obtained when market participants trade at equilibrium price. That is, it is calculated from the following expression

$$m_i = \frac{1}{N} \frac{\sum_{t=1}^{N} (p_i(t) - \lambda_i)}{p_i^* - \lambda_i} \tag{4.1}$$

where p_i^* is the equilibrium price. The efficiency is usually expressed as a percentage.

Another indicator, sometimes called the Smith's parameter, characterizes relative volatility of the price

$$\alpha_i = \frac{1}{p_i^*} \sqrt{\frac{\sum_{t=1}^{N} (p_i(t) - p_i^*)^2}{N}} \tag{4.2}$$

also usually expressed as a percentage.

Now, assuming a relative profit $\mu_i(t)$, the price $p_i(t)$ of the trader i of a unit of a good will be

$$p_i(t) = \lambda_i(1 + \mu_i(t)) \text{ with } \begin{cases} -1 \leq \mu_i(t) \leq 0 & \text{for the seller} \\ 0 \leq \mu_i(t) < p_{\max} & \text{for the buyer} \end{cases} \tag{4.3}$$

where $p_{\max}$ and $\mu_i(0) = \mu_{i0}$ are values freely set by the trader. Assuming a profit, a trader can calculate its offer: an ask (a seller) or a bid (a buyer). Just, the problem is to set the appropriate value of $\mu_i(t)$ during the bargaining. This will be discussed in the sequel.

Having calculated the price $p_i(t)$ a trader quotes it as the one at which it is willing to trade. In the Smith's experiments the price was spoken loudly. Thus it is usually referred as a *shout*.

It is usually assumed that a market consists of rational players, who maximize their profits. Also additional assumptions are taken, as for example a *spread reduction rule*, which says that all new offers have to fall within the actual lowest ask and higher bid spread. These kind of assumptions speed up convergence of the the price to the equilibrium price. The orders which do not satisfy such rules are called *invalid*. The current lowest ask is called the *outstanding ask*, the current highest bid is called the *outstanding bid*.

It is usually assumed that the orders and transactions are recorded. Different additional assumptions are made as to the presentation of the record in the publicly available table of past records. Usually matched asks and bids are erased from the table, a more favorable order may cause erase of less favorable one, and transaction may cause erase of earlier orders. These assumptions may influence the algorithms used in bargaining agents.

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.

Bibliography

[1] K. Cai, J. Niu, and S. Parsons. Using evolutionary game-theory to analyse the performance of trading strategies in a continuous double auction market. In *Adaptive Agents and Multi-Agent Systems III. Adaptation and Multi-Agent Learning*, pages 44–59, 2007.

[2] D. Cliff. Minimal-intelligence agents for bargaining behaviors in market-based environments. Technical report, School of Cognitive and Computing Sciences, University of Sussex, 1997.

[3] D. Cliff. Zip60: Further explorations in the evolutionary design of online auction market mechanisms. Technical report, School of Cognitive and Computing Sciences, University of Sussex, 2005.

[4] E. Drabik. Wykorzystanie reguł aukcyjnych do handlu energią w polsce. *Przegląd statystyczny*, 57(4):70–88, 2010.

[5] Y. Ermoliev, M. Michalevich, and A. Nentjes. Markets for tradeable emission and ambient permits: A dynamic approach. *Environmental & Resource Economics*, 15(1):39–56, January 2000.

[6] T. Ermolieva, Y. Ermoliev, G. Fischer, M. Jonas, and M. Makowski. Cost effective and environmentally safe emission trading under uncertainty. *Lecture Notes in Economics and Mathematical Systems*, 633(2):79–99, 2010.

[7] T. Ermolieva, Y. Ermoliev, M. Jonas, G. Fischer, M. Makowski, F. Wagner, and W. Winiwater. A model for robust emission trading under uncertainties. *3rd International Workshop on Uncertainty in Greenhouse Gas Inventories*, pages 57–64, September 2010.

[8] D.P. Friedman and J. Rust. *The Double Auction Market, Institutions, Theories, and Evidence: Proceedings of the Workshop on Double Auction Markets, Held June, 1991 in Santa Fe, New Mexico.* Proceedings Volume, Santa Fe Institute Studies in the Scienc. Basic Books, 1993.

[9] S. Gjerstad and J. Dickhaut. *Price Formation in Double Auctions.* Computer science/mathematics. IBM T.J. Watson Research Center, 2000.

[10] O. Godal, Y. Ermoliev, G. Klaassen, and M. Obersteiner. Carbon trading with imperfectly observable emissions. *Environmental & Resource Economics*, 25(2):151–169, June 2003.

[11] D. K. Gode and S. Sunder. Allocative efficiency of markets with zero-intelligence traders: Market as a partial substitute for individual rationality. *Journal of Political Economy*, 101(1):119–137, 1993.

[12] M. He, N. R. Jennings, and H. Leung. On agent-mediated electronic commerce. *IEEE Transactions on Knowledge and Data Engineering*, 15:985 1003, 2003.

[13] M. He, N. R. Jennings, and H. Leung. On agent-mediated electronic commerce. *IEEE Trans on Knowledge and Data Engineering*, 15(4):985–1003, 2003.

[14] M. He, H. Leung, and N. R. Jennings. A fuzzy-logic based bidding strategy for autonomous agents in continuous double auctions. *IEEE Transactions on Knowledge and Data Engineering*, 15:1345–1363, 2003.

[15] Ch. Hood. Reviewing existing and proposed emissions trading systems information paper, November 2010.

[16] G. Klaassen, A. Nentjes, and M. Smith. Testing the dynamic theory of emissions trading: Experimental evidence for global carbon trading. Technical Report IR-01-063, International Institute for Applied Systems Analysis, November 2001.

[17] F. Lopes, M. Wooldridge, and A. Q. Novais. Negotiation among autonomous computational agents: principles, analysis and challenges. *Artif. Intell. Rev.*, 29(1):1–44, March 2008.

[18] H. Mizuta and Y. Yamagata. Agent-based simulation and greenhouse gas emissions trading. In *Winter Simulation Conference*, pages 535 540, 2001.

[19] Z. Nahorski and J. Horabik. Compliance and emission trading rules for asymmetric emission uncertainty estimates. *Climatic Change*, 103:303–325, 2010. 10.1007/s10584-010-9916-4.

[20] Z. Nahorski, J. Horabik, and M. Jonas. Compliance and emissions trading under the kyoto protocol: Rules for uncertain inventories. *Water, Air and Soil Pollution: Focus*, 7(4-5):539–558, September 2007.

[21] Z. Nahorski and W. Radziszewska. Price formation strategies of programmable agents in continuous double auctions. In M. Busłowicz and K. Malinowski, editors, *Advances in Control Theory and Automation*, pages 181 194. Komitet Automatyki PAN, Oficyna Wyd. Politechniki Białostockiej, 2012.

[22] Z. Nahorski, J. Stańczak, and P. Pałka. Multi-agent approach to simulation of the greenhouse gases emission permits market. *3rd International Workshop on Uncertainty in Greenhouse Gas Inventories*, pages 183 194, September 2010.

[23] S. Phelps, S. Parsons, and P. Mcburney. Automated trading agents verses virtual humans: An evolutionary game-theoretic comparison of two double-auction market designs, 2004.

[24] E. J. Pinker, A. Seidmann, and Y. Vakrat. Managing online auctions: Current business and research issues. *Management Science*, 49:2003, 2003.

[25] Ch. Preist and M. van Tol. Adaptive agents in a persistent shout double auction. Technical Report HPL-2003-242, Hewlett-Packard, December 2003.

[26] W. Radziszewska. Auction-based market for ghg permits. Technical Report RB/16/2011, IBS PAN, 2011.

[27] J. Rust, J. H. Miller, and R. Palmer. Behavior of trading automata in a computerized double auction market. *The Double Auction Market: Institutions, Theories, and Evidence*, pages 155–198, 1991.

[28] J. Rust, J. H. Miller, and R. Palmer. Characterizing effective trading strategies: Insights from a computerized double auction tournament. *Journal of Economic Dynamics and Control*, 18(1):61 – 96, 1994. <ce:title>Special Issue on Computer Science and Economics</ce:title>.

[29] V. Smith. An experimental study of comparative market behavior. *Journal of Political Economy*, 70:111 137, 1962.

[30] D.T. Spreng, T. Flüeler, D.L. Goldblatt, and J. Minsch. *Tackling Long-Term Global Energy Problems: The Contribution of Social Science*. Environment and Policy Series. Springer London, Limited, 2011.

[31] J. Stańczak. Application of an evolutionary algorithm to simulation of the co2 emission permits market with purchase prices. *Operations Research and Decisions*, 4:94–108, 2009.

[32] J. Stańczak and P. Bartoszczuk. Co2 emission trading model with trading prices. *Climatic Change*, 103:291–301, 2010.

[33] P. Vytelingum. *The Structure and Behaviour of the Continuous Double Auction*. PhD thesis, University of Southampton, December 2006.

[34] P. Vytelingum, D. Cliff, and N. R. Jennings. Strategic bidding in continuous double auctions. *Artificial Intelligence Journal*, 172(14):1700–1729, 2008.

[35] P. Vytelingum, R.K. Dash, M. He, and N. R. Jennings. A framework for designing strategies for trading agents. In *IJCAI Workshop on Trading Agent Design and Analysis*, pages 7–13, 2005.