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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 aud 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 10

Architecture of the multi-agent system

10.1 Multi-agent systems

An agent concept is widely used in many fields like philosophy, sociology, economy, and computer science. If an auction is looked at from the economic point of view, an agent is meant as an actor and a decision maker in a model. In computer science, a software agent is a computer program that acts autonomously in its environment. This definition is very ample. The name agent can be assigned to a wide range of processes, programs and web applications that normally would never be called agents. Calling something an agent encapsulates its reasoning, actions and perceived impulses into one entity. If using this entity simplifies discussion, its use is justified.

Agents can have different features. They may be reactive, protective, learning, mobile, cooperative, etc. An intelligent agent is proactive, reactive, and interacting. This means that it has a goal that it is trying to achieve, it reacts to the changes in environment and has an ability to communicate and interact with other agents to achieve its egoistic goal. Intelligent agents can also learn, cooperate and negotiate, depending on what is needed to fulfill the task.

In this work the created agents will be intelligent with more or less developed strategies. Some would be simple reactive machines that are implemented as an entity to compare the work of other strategies and to include variety of behaviors to the market.

Agents described in this report are implemented in JADE. It means that the architecture of separated behaviors is used.

In the multi-agent approach, the trade is conducted automatically by computer programs. A programmable agent is a computer software that acts to achieve objectives of its owner. This software should exhibit the following properties:

- autonomy, which means it should be capable of making its own decisions, without referring to the user;
- reactiveness, which means it should be able to respond appropriately in unpredictable environment;
- proactiveness, which means it should be able to act in anticipation of future goals in order to meet the owner's objectives.

10.2 Agents participating in the market

The multi agent system described in this report is a model of a participant of a market for trading emission permits. The way of trading in the market is a continuous double auction described in chapter 5.

The market agent is an agent that is an entity in the system. It opens and closes the market session, receives offers from participants, checks if there is a match of an offer, makes deals and informs participants about it. The simplified state diagram for the market agent is presented in the Fig. 10.1.

A participant is an offer maker. It has its goal, which is buying or selling a certain amount of units of commodity, in this situation the permits for emissions of the unit of greenhouse gases, to reach the given condition. It receives and collects messages sent by the market. It records all the data, analyzes them and makes decisions about its actions (an action can be placing an offer or not). Its operation is consistent with Information Knowledge Behaviour Model described in 6.1. The state diagram for the participant agent is presented in Fig. 10.2. The decision of the agent depends on the strategy that it uses. Strategies are defined separately and in the current implementation a participant cannot change strategy assigned in the beginning of the simulation.

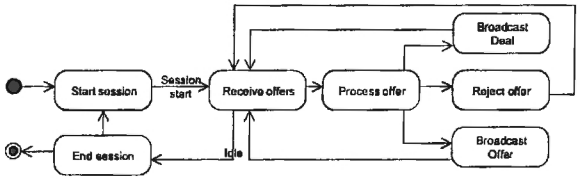

Figure 10.1: State diagram of the market agent.

10.3 Data

The system is taking information about participants from the database and saving all the data to the database. The data structure is very simple. There are four tables:

- deals – keeps the data of created deals,
- offers – keeps the data about created offers,
- participant_state – each participant records its state: the amount of the commodity that it has, and the money transfer that the participant has made,
- strategies lists the strategies with their parameters.

The structure of the database is reflected in the data structures in the implementation. Data available to the participants are:

- n – number of units of commodity that is to be bought or sold,
- λ – the limit price,
- S, B – indices informing if the participant is a seller or a buyer,
- Str – identifier of the strategy that the participant is using.

To start its operation, the market requires two parameters to be set:

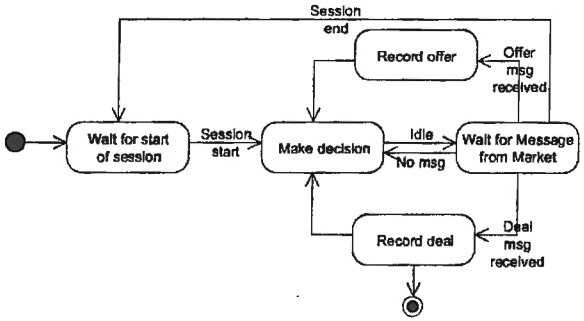

Figure 10.2: State diagram of an agent participanting in the market.

- timeLimit – time that has to pass from the last offer until market will close the session,
- fixedNumberOfSessions – number of sessions that the market will have, it is connected to the number of units that have to be sold or bought during whole duration of the market.

10.4 Architecture

Because there are only two types of agents defined, the structure of the system is very simple. The hierarchy of packages is presented in Fig. 10.3.

Package *agents* contain the definitions of the agents, package *behaviors* include all defined behaviors of the agents. *Datastructures* include all custom classes defined in the system as Offer, Deal, Participant, etc. It also includes classes that define data access objects. The package *launcher* includes the class responsible for launching the defined test case. Package *strategies* include the classes that implement strategies.

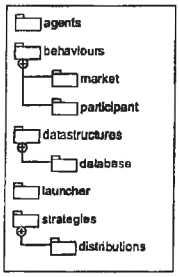

Figure 10.3: Hierarchy of packages in the system.

10.5 Communication

Communication between the agents is realized by sending predefined messages. The content is a Java object. Communication is simple but sufficient to simulate the market. The full list of communicates sent between the market and participants agents is presented in Tab. 10.1. Participants are sending offers only to the market agent, there is no information exchange between participants.

Sender	Receiver	Speech act	Content	Description
Market	Participant	INFORM	Integer	Number of the session that is starting
Market	Participant	CANCEL	Integer	Number of the session that is finishing
Participant	Market	PROPOSE	Offer	Offer that participant wants to place on market
Market	Participant	FAILURE	Offer	Offer is not valid
Market	Participant	CONFIRM	Offer	Offer was registered on market
Market	Participant	CONFIRM	Deal	Match was found for the offer, there is a deal

Table 10.1: Table of communicates of the agents in the system.

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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