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A Practical Approach for Researching Trading Agents' Behaviour in a CDA Environment[1]

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Abstract. During the last decade, there has been a huge increase in the volume of Internet business transactions which in turn led to the emergence of a new field of scientific research - agent-based computational economics. In order to be able to conduct successful transactions, agents must have appropriate strategies to participate in trading negotiations. This paper is aimed at investigating the process of multi-agent negotiations in continuous double auction (CDA) and describes one possible approach for solving the problem of resource allocation in a distributed computational environment. Our goal is to present a new software tool for e-auctions simulation and to investigate bidding agents' strategies. Via a series of experiments we prove that this new software application sufficiently models the process of making transactions in CDA. We propose a new method for quick and reliable strategy comparisons. Using this novel method, we can choose a bidding strategy that ensures the most effective resource allocation.

1 Introduction

The field of agent-based economics is an intersection point of computer science and microeconomics. Research in this field is carried out in several basic directions:

- Search for efficient mechanisms for decentralized and distributed computational systems control;
- Investigation of economic problems via an agent-based simulation and
- Implementation of intelligent agents for managing the buying and selling processes performed on behalf of their users in an e-commerce environment [1, 9].

The reasons which led to the increased interest in applying agent-based technologies in e-commerce are:

- Internet has turned from a hypermedia environment for information exchange into a convenient and easy to use business environment. This provides not only varied communication channels, but also an integral infrastructure for conducting e-business;

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- The amount of information concerning different goods and services on the Internet has increased immensely and it's processing takes much more time then before;
- Software agents possess certain qualities and characteristics which enable them to effectively represent (and in some cases entirely replace) their owners in gathering and analyzing relevant information and making decisions with whom, when and at what price to strike a deal.

The second part of this paper presents the existing software systems for e-market simulation in brief. The necessity for creating a new environment that models the behavior of agents participating in e-auctions is substantiated. In the third part of the paper MASECA, a new software environment for agent-based e-auctions modelling, is described. The experiments that have been conducted with the system, prove its applicability for researching agent strategies for bidding in the fourth part. Emphasis is put on the proposition for an effective method of comparison between the bidding strategies. At the end, the obtained results have been summarized.

2 Modern Systems for E-Market Modelling via Auctions

There are various research projects in the field of e-commerce for scarce resources allocation via auctions, but only a small number of them use agents as actors and e mploy different market mechanisms. For example, Kasbah [2] enables agents to engage in bilateral negotiations on the basis of three simple functional dependencies for specifying the value of next bid/offer. The system stimulates only one double auction and after improving some of its functions it is now being used for teaching students at MIT and is known as Market Maker. Fish Market [6] is a project of Artificial Intelligence Research Institute in Barcelona. It emulates a very narrow field in e-commerce by supporting only Dutch auction. Michigan Internet Auction Bot [11] is a configurable server for several types of auctions. It has been created on the basis of the annual Trading Agent Competition, TAC, which stimulates interesting research on autonomous agents' behavior in bidding for a packet of various services.

The abovementioned systems have many disadvantages. Firstly, they mainly simulate only one type of auction. Exception from this rule is the Auction Bot System, which models many types of auctions, but there it is bid for a batch of interrelated goods and services. Secondly, these MAC do not provide possibility for choosing from many predefined bidding strategies. Thirdly, it has to be pointed out that there is a lack of options for creating and experimenting with strategies defined by the user of the corresponding system.

In order for these limitations to be overcome, we created a new platform for e-auctions modeling called *M*ulti *A*gent *S*ystem for *E*lectronic *C*ommerce with *A*uctions (MASECA). MASECA is a software system for simulating and experimental researching of multi-agent negotiations via auctions. Participants try to cooperatively maximize market efficiency by using different built-in bidding strategies. Up to now, the bidding strategies most commonly employed in online auctions have been realized in the systems: Fixed Markup (FM), Zero Intelligence Unconstrained (ZI-U) and Zero Intelligence Constrained (ZI-C) [4], Zero Intelligence Plus (ZIP) [3], RB Strategy (RB) [10] etc.

3 General characteristic of Multi-Agent System for E-Commerce via Auctions – MASECA

3.1 Functional Capabilities of the System

MASECA is a software instrument for investigating different negotiation scenarios by online auctions. Under these scenarios the object of interaction is coming to an agreement between agents for a win-win type of deal and the goal is maximizing total profit of all participants in a specific auction under given market conditions. Not only does the environment provide virtual space for the existence of auctions and agents, but it also enhances interaction between agents and market and is a place for information storage. It gathers deals history, processes statistical information about negotiations and struck deals. This way MASECA infrastructure helps market participants in making bidding decisions. This platform allows experimenting with a variety of built-in agent strategies and for the purposes of such an experiment the values of some or all of their parameters can be changed. On the other hand, there is a possibility for using outside strategies and the connection can be established during experiments via a proper protocol for sending and receiving messages.

3.2 MASECA's Program Implementation

In choosing a development environment for system realization, comparative analysis for finding the strengths and weaknesses of the several types of systems has been applied. We concentrate our attention on the integrated development environment of Borland Delphi as a tool for creating a system for e- market modeling because of the high quality, security and reliability of the developed applications. Delphi ensures a relatively large multi platform, because from the source code a new code for the platforms Microsoft Windows, Microsoft .NET Framework and Linux can be generated. The new system will be installable and will mainly use Wintel-computer systems.

All basic possibilities for communicability (activation and deactivation of a separate thread process, sending and receiving messages from the environment, processing registered events, etc.) are present in an objects' hierarchy. The functionality of separate objects is enhanced in the hierarchy's upper levels, in accordance with objects' specifications.

While realizing the environment for modeling e-commerce, an effective protocol for exchanging information between market participants has been developed. It has been optimized and contains the minimum number of types of messages, which are exchanged between an agent and an auction. More details about MASECA's peculiarities are given in [5].

4 Comparative Analysis between Strategies Applicable to Agent-Based Negotiations under CDA Conditions for Heterogeneous Populations

4.1 Methods and Criteria

Methods for strategy evaluation for heterogenous populations are based on two diffe rent approaches. The first one of them (applied by [7, 8] etc.) consists of a comparison between the efficiencies of the strategies for balanced populations (where strategies are in the same ratio during the experiment). The second approach was suggested by Walsh et al. (2002) and studies unbalanced populations by means of evaluating replicator dynamics (RD). The criteria that are used for comparing and evaluating strategies are once again market efficiency, average transaction price, convergence coefficient α , etc. Unfortunately, all these indices reflect rather the overall efficiency of the whole population (group) of agents (regardless of the strategy one or another group of it uses), than direct impact of separate strategies. On the other hand, it is necessary that a large number of planned experiments be conducted in order for each of the participating strategies' impacts to be shown clearly and this involves a certain expense of machine resources and processing time.

For removing the abovementioned shortcomings of the methods for strategy evaluation and comparison applied till now, a new methodology is proposed in this work, it is based on the former approach and it consists of the following:

1. The strategies that are to be compared are specified and this includes identification of the type and specific parameters of each of them.

2. All the agents that are to participate in negotiations are divided into 4 groups:

a) group A - sellers with strategy S1;

b) group B - sellers with strategy S2;

c) group C - buyers with strategy B1;

d) group D - buyers with strategy B2.

The number of agents in each group for a given experiment is fixed.

3. The market conditions under which the experiments is to be conducted are determined. They include constraints of every agent (producer price if the agent has the role of a seller and reasonable price if it is a buyer). Usually, modeling market dynamics by a market shock is expected.

4. Duration of the time interval in which certain market conditions apply is provided (in days).

5. The number of experimental tries is provided. With their help accidental factor influence on experimental results is minimized.

The main peculiarity of the proposed methodology is that, for each experimental session, conducting two mutually complement tries is in order: one for the given strategies by groups (see point 2 of methodology) and the other one is for the same groups but with swapped strategies. This means that if at the beginning there have been provided groups with numbers and strategies as follows:

A - S1; B - S2; C - B1; D - B2,

then in the complementary try the following groups, presented as pairs of numbers and strategies, will be generated:

A - S2; B - S1; C - B2; D - B1.

The number of agents (and the agents themselves together with their price limitations by groups is preserved, but the strategies with which each group participates are changed (sort of inverted).

The main advantage of this approach is that, each pair of strategies (for sellers: S1, S2 and for buyers B1, B2) is consequently placed in one market situation (first try) and in the situation in which its opponent strategy was placed during the first try (complementary try). If total profit by groups (A,B,C,D) is registered for the main and the complementary tries, a fairly objective comparable index of the studied strategies (S1,S2,B1,B2) can be obtained.

During the conducting of experiments the following criteria of comparison of analysed strategies have been investigated:

a) average profit for a given strategy and the whole group of agents using this strategy (for session, for a try);

b) average profit for a given strategy for an agent (for session, for a try);

c) portion of the profit for a given strategy, as a portion of the total theoretically possible and actually realized profit.

4.2 Experimental Setting

As a tool for making the analysis the system MASECA was used, which fully co mplies with the requirements set by the new methodology for evaluation and comparison of strategies. Windows XP Professional Edition operating system with the following configuration: CPU AMD Athlon (tm) XP 1800+, 1.53 GHz, 768 MB RAM is used.

The experimental conditions of the e-market that is being modeled are:

- number of sellers 11;
- number of buyers 11;
- marginal prices of sellers before market shock:

0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25

- marginal prices of buyers before market shock:

0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25

- marginal prices of sellers after market shock:

1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75

- marginal prices of buyers after market shock:

1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75

Theoretically possible profit (total for all struck deals) for one try before the shock is 7.50, and equilibrium price is 2.00. After the shock theoretical profit is preserved (7.50), and equilibrium price rises by 0.50 to 2.50.

Strategy parameters are given in accordance with the recommended ones, presented by their authors.

The number of sessions before market shock has been set to 5.

The number of sessions after market shock has been set to 5.

The number of tries (pairs: a try and a complementary try) has been set to 50.

A series of experiments has been conducted, in which various ratios between the numbers of agents in groups A and B (and correspondigly C and D) have been set: 1:10, 2:9, 3:8, 4:7 и 5:6.

4.3 Estimating the Relevance of the Methodology - Experiments, Results and Analysis

Before actual experiments for comparing and evaluating different strategies can be conducted, it is necessary to be proven that the suggested methodology can provide relevant (objective) results and sufficiently small (permissible for analysis purposes) error.

In order for the relevance of the methodology to be determined and for the possible error to be estimated a model experiment was conducted in the beginning, in which instead of different strategies only one was used (in this case the most complicated realized strategy, RB, was applied). It is expected that if the methodology is relevant, then with one and the same strategy the adopted evaluation criteria will be the same or similar with precision near the error of the evaluation method, which is being tested. The same market conditions apply that were described above and the conducted experiments involve the following ratios of the numbers of bearers of competing strategies: 1:10, 2:9, 3:8, 4:7 and 5:6. The conditions of the model experiment are identical with those of the experiments that are to be really conducted for comparing different strategies

The results obtained experimentally are summarized in the following Table 1.

Table 1. Summary of results – average profit by strategies from all conducted experiments, with the ratios between strategies taken into account

Strategies' ratio	1-10	2-9	3-8	4-7	5-6
S1	0.43	0.54	1.06	0.91	1.66
S1' (complementary to S1)	2.96	2.74	2.33	2.43	1.65
S2	3.03	2.75	2.16	2.45	1.64
S2' (complementary to S2)	0.41	0.56	1.14	0.91	1.63
B1	0.12	0.56	1.07	0.58	1.02
B1' (complementary to B1)	3.93	3.59	2.93	3.42	3.17
B2	3.84	3.58	3.17	3.45	3.10
B2' (complementary to B2)	0.14	0.54	1.03	0.65	1.00
AvgS1-S1'	1.70	1.64	1.69	1.67	1.65
AvgS2-S2'	1.72	1.66	1.65	1.68	1.64
AvgB1-B1'	2.03	2.07	2.00	2.00	2.10
AvgB2-B2'	1.99	2.06	2.10	2.05	2.05
DeltaS1S2	-0.02	-0.01	0.05	-0.01	0.01
DeltaB1B2	0.04	0.01	-0.10	-0.05	0.04

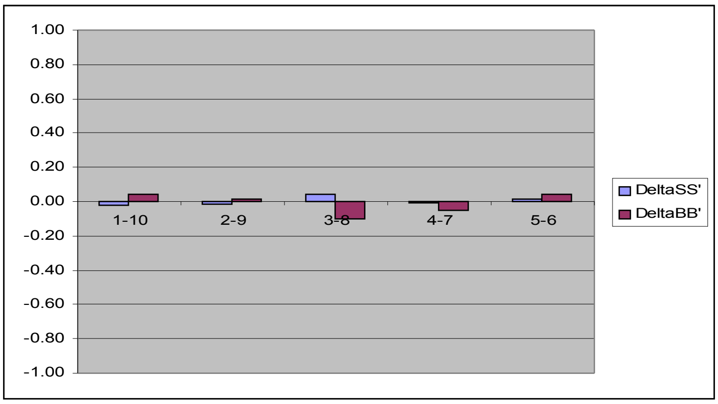

Fig. 1. Maximum difference (error) when comparing obtained results for average profit

It can be seen that the maximum difference (error) in comparison of obtained results for average profit according to strategies does not exceed 0.10 (obtained for ratio between strategies 3-8), which is amounts to 5% of the average realized profit of all strategies (1.86). This error is due not to the methodology of comparison but rather on the random determination of marginal prices for agents with different strategies and also on the random character of an array of elements in the process of negotiation, which is built in the strategies on purpose [3, 4, 10]. To a certain extent this error in strategy comparison according to suggested methodology would be reduced (to 3-4%) when increasing the number of tries in the experiment, but for the purposes that this development has a deviation of 5% totally complies with the relevance that is required by the methodology.

4.4 Comparison of the RB and ZiC strategies

In order for evaluation and comparison of the strategies RB and ZiC to be made a series of experiments under the conditions that have been described above was conducted. The results were presented in the following table and graph:

Table 2 Average profit for individual strategies (S-RB,S-ZiC,B-RB,B-ZiC) with ratio 1-10, 2-9, 3-8, 4-7, 5-6.

Strategy Description	1-10	2-9	3-8	4-7	5-6
Avg-RB	1.935	2.040	2.089	2.079	2.150
Avg-ZiC	1.705	1.633	1.550	1.549	1.489

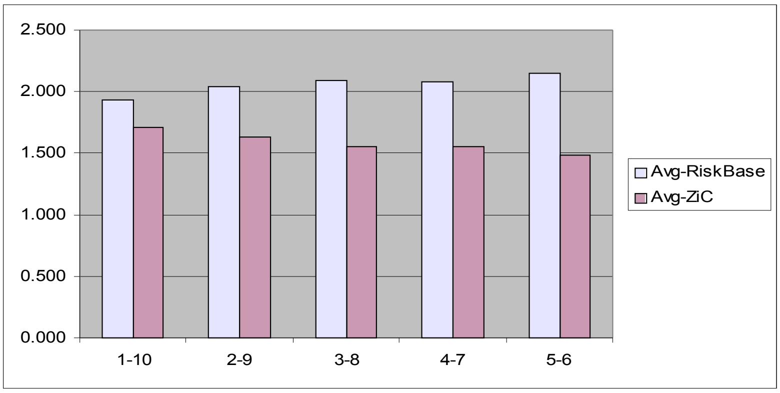

Fig. 2. Average profit for individual strategies (RB and ZiC) with different ratios

In order for the presented results to be analyzed, it is useful that the whole sequence of se ssions (from 1 to 10) be divided into several parts:

-P1: initial (including the first 2 sessions), in which agents act without preliminary information about the market and make their initial proposals in accordance with the algorithms built in their strategies;

-P2: established (Session 3, 4 and 5). In these sessions there is some collected initial information about market conditions (from the previous two sessions) and adaptive algorithms (if there are such) are applied.;

-P3: including Session 6 and 7, where a price shock is set, in which agents must aim at striking deals at the higher new level of the equilibrium price;

-P4: again established part (Session 8, 9 and 10), where agents can search for an optimal transaction level and try to maximize their profits.

When comparing data about activities of agents with different strategies, the following regularities can be observed:

1. In part P1 regardless of the ratio of the number of agents with different strategies, for the RB strategy there is a clear big difference between profit of seller and profit of buyer (on behalf of buyer). This is explained by the asymmetry while generating the initial proposal: with buyers initial proposals are limited to a price of 0.00 and may be very close to it (under the condition that there are no seller propositions on the market). Unlike this, sellers put initial price without having information about the price ceiling (maximum price at the market) and this is realized as a function of agent's limited price and some random element. This is why agents – sellers with low limited price can start with very low random propositions which will drive the price of initial transaction drastically down and as a result sellers's profit (as a whole) will be lower than that of buyers.

With the other strategy – ZiC – there is no such a great difference between the profits of seller and buyer groups, but still there is a differentiation depending on roles. In this part (P1) reaching equilibrium price when striking deals using the ZiC strategy is slower in comparison with the RB strategy and continues even in the beginning of part P2.

2. In part P2 agents with the RB strategy have already reached equilibrium market prices and the profits gained are significantly higher than those of the agents using the

ZiC strategy. The strategy is more stable and does not allow random deviations, as those that can be observed with ZiC.

3. In part P3 (price shock) there is variation in the values of realized profits for both agents using the RB strategy, and those using the ZiC strategy. With RB hesitations in profits immediately after the shock clearly have a large amplitude and small duration. However, for agents using ZiC profit varies with smaller amplitude but for a longer period of time (in some cases it continues to the middle of next part (P4)). It must be noted that buyers' profit is again higher because of the direction fo the price shock (increase in limiting prices and consequently in the equilibrium one), because agents' reaction is inert and in the period before finding the new equilibrium price (transition from old to new) deals are struck at lower prices.

4. In part P4 variations in realized profit have a tendency to fading, and this can be observed clearly for agents using the RB strategy.

5. In all parts the profit realized by the groups (sellers and buyers) with the RB strategy are higher (with no exception) than those of the opponent strategy. As it can be observed from the graphical data enclosed above, there are variations in the level of average profit for a given strategy depending on market conditions (respectively the number of Session), but no doubt agents employing the RB strategy reap higher profits.

6. Depending on the ratio of the numbers of agents in each of the groups with different roles and strategies (see **Fig. 2**) it can be seen, that the difference in profits for individual strategies strengthens when approaching the ratio of the numbers of agents with different strategies to 1.

7. Regardless of the ratio of the numbers of agents in each of the groups with different roles and strategies very high efficiency cannot be obtained (realization of theoretically possible transactions, e.g. a total profit of 7.50), because random element is heavily grounded in the ZiC strategy. In reality the total actual profit is between 7.20-7.30, which is 95-97% of theoretical profit.

This new research approach for comparison between stratagies reveals new relationships between the ratio of the numbers of agents using corresponding strategies and the results CDA shows for heterogeneous population.

Conclusions

In this work the newly created flexible program system for e-market simulation, named MASECA, has been described. The goal is by means of this software platform to research the agents' behavior in online auctions. Our efforts are aimed at studying CDA, since this is the most widespread mechanism for trading with currency and securities. Experimental results of the software proves that it is an appropriate instr ument for evaluating agent strategies. A new methodology for experimental research of the realized strategies in heterogeneous populations of agents has been proposed. On the basis of the results obtained by the new methodology for agent strategy comparison, proposals for increasing their efficiency have been made.

Future research directions are related to prove through dispersion analysis whether strategies' parameters affect their effectiveness, tuning parameter specifications and optimization proposals.

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