

# Agent Exchange - Virtual Trading Environment

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**Abstract.** Agent Exchange is a virtual trading environment serving as a test bed for experiments with market simulations, trading strategies and auctioning techniques. Agent Exchange is the distributed environment implementing up-to-date knowledge from multi-agent systems and secure communication. The developed agent community consists of independent agents communicating via defined protocols and ontology. The secure agent communication is an important part of this project. Roles that agents can play in the Agent Exchange community are Trading-agent, Bank-agent, Exchange-agent, Scenario-agent, User-agent, and Central trading authority agent. This paper describes the design of the Agent Exchange project, its functions and implementation details.

## 1 Introduction

Agent Exchange (AX) is a test-bed for experimenting with advanced trading strategies in an Agentcities [1] distributed environment. By developing the publicly available agent-based virtual market we aim to stimulate the research in the area of distributed decision making for B2B and B2C, and increase exploitation of the Agentcities environment for other than tourism-like services. The developed AX environment serves for experiments in electronic markets and as a tool during courses at artificial intelligence that are given by Gerstner Laboratory, Czech Technical University in Prague.

Provided infrastructure consists of six agent roles. Five of them (Trading-agent, Bank-agent, Exchange-agent, Scenario-agent and User-agent) form business community and participate on trading. The minimal number of agents acting any role is one and maximum number is unlimited for any agent role in the business community. The sixth one (Central trading authority agent) supports the other agents by broadcasting information about existence of community members. There is only one instance of this agent in the AX at this moment. Each agent has unique certificate including agent's role, and keys for encrypting or signing messages. The developed protocols and ontology allow start of the community and its negotiation. Traders can control the accounts in banks, get information from exchanges, and put the bid to sell/buy to the exchange. Exchanges can check traders' solvency and realize commodity transactions.

The AX environment applies security mechanisms of encryption and signing provided by X-Security [2] package. Signing and encrypting of whole and part

of message are used in the communication. The implemented auction model is Continuous Double Auction. The defined communication protocols and ontology are the only stuff that must be supported and utilized by the agents acting in AX. Developers can the run pre-prepared agent community and are also encouraged to design and implement new ones. Both of adaptation and substitution of existing agents are allowed in the AX virtual market environment.

This paper contains the following parts. Section 2 aims to definition of seller and buyer, and their negotiation. Section 3 describes social model and their advantages for agents acting on virtual markets. Section 4 aims new developed virtual trading environment, its components and agent communication details.

## 2 Market Negotiation

The trade is usually based on the exchanging of commodities and services. The one who produces any commodity is the producer of this commodity. Equally the consumer is the one that consumes commodity. In this description we assume one of the exchanged commodity being universal currency, e.g. money. Having defined money we can describe seller as the one who owns commodity different to money and wants to exchange this commodity to money. On the other hand we are allowed to define buyer that has money and wants commodity. The seller wants to gain as much money as possible and buyer wants to pay as little as necessary to gain the commodity.

The seller and buyer are roles on the market and anyone is allowed to act both roles in the same moment and resell bought commodity to others. Beside seller and buyer there is a coordinator (manager) organizing the market negotiation. Coordinator role can be played by anyone playing seller or buyer role, or by another one subject, which is not interested in buying or selling commodity. This subject provides services of coordinating the trade for buyers and sellers.

All sellers and buyers have set limit value of the commodity. Each seller has minimum value he is compliant to get when selling one piece as well as each buyer is compliant to pay for one piece only some maximum value. These is a *private value* of a trader. In case of disclosure of this information other traders can modify their prices offered to the one with tapped limit value. The result of disclosure is reduction of a profit of handicapped trader. Beside the private values of particular traders there is the *common value*. Common value is a result of the negotiation mechanisms of traders and describes how the market values the commodity. Taking common value into account traders can increase their profit (e.g. sellers can asks higher price then his minimum one is if he assume to get it - commodity is sold and profit increased).

Various mechanisms exist for finding a trade partner and accomplishing the commodity and money exchange. To select a mechanism one must assume that the trade is one-shot or repeat. Realizing the repeated long-term contract one can get better conditions (e.g. price) from the seller or buyer than conditions got if the trade negotiation is started every time from null. Even in long-time

contract it could be possible to get temporary worse condition (e.g. pay more) then actual one-shot market offers. It takes place if the contract provide better conditions over whole period of the contract than finishing it because of temporary conditions. For one-shot sale and purchase it is more effective to find seller or buyer offering the actual best price. The last thing that trader must realize is whether he knows the common value of the offered/required commodity. Suitable mechanisms can reduce the lost and enlarge the profit. The main mechanisms are Contract Net Protocol (CNP) and auctions. CNP was originally described by Smith in [3]. It is based on calling others for proposals and selection of the offer that best fits the requirements. Auctions collect offers of interested sellers and buyers. Different auction mechanisms require different bidding and can reach different results.

Auctions are supposed to be significant in the future of electronic trading because auction is setting the price of goods according to the actual demand and supply. Reynolds in [4] defines auction as a competitive method of allocation limited commodity. There are more then one types of auction and not all of them are based on ascending prices.

Reynolds [4], Sandholm [5] and others (e.g. [6]) divide auction into 4 basic types depending on sealed or open bids and ascending or descending price. As another auction type they consider Double Auction. Almost all various auctions used in the world can be described as variants of the 4 basic and Double Auction. Unfortunately this system of classification is not consolidated in names of types. We use the same names for auction types like [4] and [5] do. The basic 4 auctions are:

- English (ascending-price),
- Dutch (descending-price),
- First-Price sealed-bid (first-price),
- Vickrey (uniform second-price).

Another auction type is Double Auction widely used in the variant called Continuous Double Auction (CDA). We decided to use CDA as a basic auction type for Agent Exchange. Other types of auctioning mechanisms are also envisaged to be implemented.

### 3 Social Models

As mentioned before the trade is based on the commodity exchange. The conversion rate (ratio of common values of exchanged commodities) mainly depends on market demand and supply of particular commodities. The real price that seller can get and buyer pays also depends on their knowledge about the market and other traders. Not all traders know all the others, not all traders negotiate about the price and try to pay as least as possible, and not all traders can wait to expected seasonal price-cutting. Having knowledge about other traders' desires, their private values, negotiation abilities, and seasonal trends can help

trader considering this knowledge to increase the profit. Not only knowledge about competitors but also about teammates sharing the same goal can improve bargaining abilities.

The work [7] defines the concept of a social knowledge. Social knowledge in a trading environment describes the others' behaviors, offered and required commodity, amount of commodity and private values. Teammates provide all information accurately because they contribute to maximizing the profit of the team. On the other the information the competitors announce is only the one they suppose to increase their own profits. Information that the trader never says to others is his *private knowledge*; the information given to the trade partners (e.g. during market negotiation) is the *semiprivate knowledge*; and the information accessible to everyone (e.g. trade's communication address) is the *public knowledge*. To get information about the others one can ask them or use subscribe/advertise protocol if others are compliant to provide required information. Everything else about other traders must be estimated from their announced requests, responses to requests for offers in contract net protocol, and their bidding on auction if bids are not sealed. In multi-agent systems there is an acquaintance model serving as the tool for knowledge representation. Typical example of modern acquaintance model is the tri-base model [8].

## 4 Agent Exchange

AX business community roles (See figure 1) are Trading-agent, Bank-agent, Exchange-agent, User-agents and Scenario-agent. Another agent is Central trading authority agent that does not participate on trading but is an important member in open communities.

### 4.1 Agent roles

- **Trading-agent** sells and buys commodities. Its aim is to make profit. Trading-agents are allowed to cooperate.
- **User-agent** is an interface between a human user and the Trading-agents. This agent manages the team of Trading-agents that a human user owns. Each team has its own team-leader.
- **Bank-agent** organizes payments for the inter-agent trading. The Bank-agent administers the money and commodity accounts for the agents that ask Bank-agent to do it.
- **Exchange-agent** is responsible for organizing the trades among the Trading-agents. This agent is envisaged as an open environment for implementing various auctioning strategies.
- **Scenario-agent** influences the trading environment by shipping and delivering specific commodities into/from the market.
- **Central trading authority agent** informs Trading-agents about existing Bank-agents and Exchange-agents. The other function of this agent is providing money and commodity to newborn Trading-agents to allow them deal on the market.

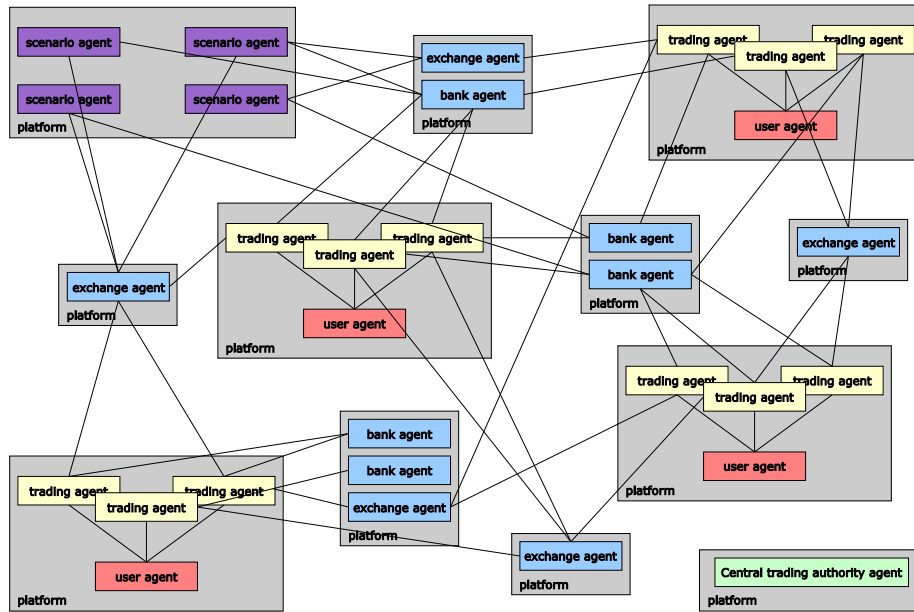


Fig. 1. Agent Exchange community structure

**Trading-agent (TA)** The Trading-agent is an agent that exploits its resources and rationality in order to make profit on transforming different types of resources by indirect interaction with the other Trading-agents. The interaction of Trading-agents is made available by the Exchange-agent. Trading-agent operates according the orders from User-agent. The easiest task for the Trading-agent is to exchange specified commodity on specified auction. More difficult task is to exchange defined amount and price of the good but the selection of the auction is up to Trading-agent. The most difficult task is to cooperate in trading with the teammates. It is most difficult but by the cooperation the team can get higher profit. Cooperation of Trading-agents and the User-agent is described in the following section.

**User-agent (UA)** The User-agent serves as an interface between team of Trading-agents and a human user. The task of this agent is to manage the Trading-agents that a particular user owns and to collect and show up-to-date information about accounts and Trading-agents' states. The team of the User-agent and subordinate Trading-agents tries to reach the profit and satisfy the human user owning the team. The team is required to contain intelligence allowing trading and some graphic user interface (GUI) to present state of the team to user.

The easiest way how to create team of a User-agent and Trading-agents is to create one agent compiling the features of both required agent types. This new agent can be viewed as one-member team with implemented graphic user interface. It does not need any social model of the teammates because of nonexistence of them. The social model that this agent and also agents using other variants of cooperation needs is the model of competitors and Exchange-agents and their exchanges on that Trading-agent trade. This variant is required in some simulations of lone self-oriented investors without sharing resources. This model is only one that is implemented in the AX project now.

For the further use by another developers we described protocols and ontology used by Trading-agent to allow developers implement their own Trading-agents and User-agents. Using these protocols and ontology developers are able to implement an interface between the Agent Exchange community and their expert and decision making systems. They do not need to implement their existing software again to prove it in the Agent Exchange.

**Bank-agent (BA)** The Bank-agent is a registering agent that organizes payments for the inter-agent trading. The Bank-agent administers accounts for subscribed agents. Besides money there are other commodities registered with the Bank-agent. The Bank-agents serve as a virtual commodity storage. Thus Bank-agent contains databases of agents' accounts. Each record contains account number, identification and communication address of owner, commodity that is stored on this account, state (number of items or money), and a list of bookings. The booking is record about amount of commodity that account owner trusted the Exchange-agent to manipulate with it. All the Bank-agents are required to act trustworthily. Contemporary Bank-agent cannot ask charges for its services. The feature of service charges will be implemented if necessary in any simulation.

**Exchange-agent (EA)** The Exchange-agent receives offers to buy or sell from Trading-agents. All bids must contain offered commodity, requested commodity, price, deadline till the offer is valid, and commodity or money booking certificate. The Exchange-agent checks all necessary bank accounts whether the seller owns enough commodity and buyer enough money. When conditions to satisfy new-come offers can be accomplished the exchange is done by bank orders to exchange the money and commodity. Then the seller and buyer are informed about the executed transaction.

As a basic auction model we implemented Continuous Double Auction (CDA). This one is also used in another virtual trading environments such as TAC [9]. In the real financial world CDA is used in stock exchanges (e.g. NYSE New York Stock Exchange [10]). The CDA is the auction that never stops and sellers and buyers place they required and offered prices independently. At the moment when the requirements of any seller and buyer meet, the exchange of the commodity and money is executed.

We decided to allow to exchange only money to commodity and commodity to money on the auction. Barter is not allowed now and because the real trading is based on money. We plan to use it only if simulation explicitly requires it. Although barter is not used in the AX now it can be allowed anytime when a simulation requires it. Amount of sold and bought commodity is allowed to be bigger than 0. Commodity unit and virtual money unit are divisible.

**Scenario-agent (SA)** The Scenario-agent is the first producer and final consumer of all commodities in the AX market environment. Scenario-agent sells and buys the commodity according to orders from Power User (human user, who controls the commodity flow to/from the Agent Exchange environment). The Scenario-agent acts in causal manners that could be informally described and publicly known in a possible combination with a random factor. Scenario-agents act directly on exchanges. To control Scenario-agent Power User can use predefined scenario file describing scenarios of periodic affecting or graphic user interface for immediate affecting. Each record in the scenario file contains these data:

- **Probability** of performing the action,
- **Time** of action that defines start-up of the action,
- **Type** of action defines if the commodity has to be sold or bought,
- Offered or requested **commodity**,
- Commodity **amount**,
- Commodity **price**,
- **Exchange** which will be asked to provide the action.

The loss making and ability to make money and commodities according to the orders is the reason why Bank-agents are required to receive commodity not only from the other Bank-agents as usual in the ordinary transactions. They have to receive commodity from Scenario-agents too to allow them create products for selling. Thus the Scenario-agent is allowed to generate commodity for influencing the market.

The procedure of influence is as follow. According to orders read from the file, or received from the Power User via GUI, Scenario-agent orders Bank-agent via Central trading authority agent to create both of source account and target account if it is necessary. Next step is generating commodities that have to be sold or money that have to be spent. Then the Scenario-agent sends relevant requests to exchanges. Scenario-agent requests them to buy and sell commodities at the amount defined in scenario file or by Power User. When matching bids are found the Exchange-agent performs the trade via standard protocols for commodities exchange.

## 4.2 Communication Ontology

We use three ontologies for messages construction: Management-ontology, Bank-ontology and Exchange-ontology. Management-ontology provides messages controlling the community. Bank-ontology is the main one for business communication and serves all messages that other agents send to (and receive from) the

Bank Agent. Trading Agents communicate to the Exchange Agent via Exchange-ontology. Bank-ontology and Exchange-ontology form group of inter-agent business communication ontology.

### 4.3 Communication Security

The business communication messages are confidential and often contain the orders to transfer money and other commodities. To secure the communication within Agent Exchange we use the X-Security model [2]. This model provides partial security for community members and is being tested on the Agent Exchange community.

X-Security model supports securing of whole message content by signing and encrypting as well as securing a defined content part. When the complete content is secured the message is extended with new slot called X-Security. This slot contains identification of security method and used keys. When the content is signed this slot also contain the signature. The information included to X-Security slot is necessary for the receiver of the message to choose appropriate method for decryption or signature check. When only part of message content is secured the message content contains X-Security information beside the secured part.

Signing specified part of message serves as an authorization of another agent to perform some action. The authorized agent can copy the authorization and send it to agent that has to perform this action, which originally could be requested only by authorizing agent. The agent performing the requested action has a glue that the action was really requested by agent who can do it or this agent dedicated another one to request it.

Authorizing another agents in AX is necessary because exchanging is provided by sending orders to Exchange-agents. The Exchange-agent receives bids and relevant authorization, which are signed by Trading-agents, for commodities that have to be sold. After finding corresponding bids The Exchange-agent orders Bank-agents, where commodities the goods and money to be exchanged are stored, to transfer them to the buyer's and seller's accounts. Bank-agents can do it only after previously receiving of correct authorizations that account owners provide to the Exchange-agent. This one passes them to the Bank-agents to gain access to the commodities and to give Bank-agents proofs that the commodity owners really requested transfers of the commodity and money.

The basic communication security functions for AX business community are provided by Security certification authority agent (SCA). Each agent is required to register its security certificate at SCA to be allowed to use secure communication. The security certificate contains agent's identification, time of certificate validity, agent's security level, public keys, keys identification and type (e.g. RSA/1024 or SHA with DSA/1024). SCA maintains actual valid certificates of all agents and provides them to every agent by request.

When any agent receives a message and the agent does not have appropriate certificate for its decryption or signature-check, the agent asks SCA for it. After receiving the certificate the agent can decrypt message or check message signature and continue in communication with the original message's sender.

#### **4.4 Implementation and Future work**

Agent Exchange is the new publicly available virtual multi-agent test-bed. The aim of our research is to provide the virtual electronic market environment to developers who want to test and prove their algorithms for real electronic trading. For implementation we use Java 1.4 and Jade 2.61. The AX community contains agents of six different roles. These agent roles allow implementing almost any subject participating on trading in real business world.

The future work that has to be done is an improvement of Trading-agent strategies to allow them cooperate and extending the Bank-agent by the service charges collecting. Next step of our research we see in interconnection of the Trading-agent and the Scenario-agent to allow any agent transform commodities.

### **5 Conclusion**

E-business and virtual marketplaces become significant in these days. The AX project aims to develop an agent-based virtual market infrastructure that can be used as a test-bed for electronic software trading agents before their run in the real competitive environment. The developed system does not contain any central system that is necessary for trading. Any agent participating on the commodity exchange is substitutable and can be removed and also added to the market anytime during the run of the simulation. Publication of used protocols and ontology allows developers to design new agents (acting defined roles) and after implementing the interface connect and test existing system in virtual market environment. As an example of multi-agent system the Agent Exchange is used by students attending courses at artificial intelligence that are given by Gerstner Laboratory, Czech Technical University in Prague.

Source codes of Agent Exchange project are available at the project official web-page [11].

### **6 Acknowledgement**

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