AGENT-BASED SIMULATION OF ELECTRONIC MARKETPLACES WITH ONTOLOGY-SERVICES

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ABSTRACT
Agent technology has been successfully applied to the Electronic Commerce domain, but the diversity of the involved actors leads to different conceptualizations of the needs and capabilities, giving rise to semantic incompatibilities between them. It is hard to find two agents using precisely the same vocabulary. They usually have a heterogeneous private vocabulary defined in their own private ontology. In order to provide help in the conversation among different agents, we are proposing what we call ontology-services to facilitate agents' interoperability. More specifically, this work presents a multi-agent market simulator with ontology services. The system includes agents that provide services that allow other agents to communicate with each other in order to reach an agreement, ensuring that both parties are able to understand the terms of negotiation.

Keywords: Intelligent Agents, Simulation, Electronic Markets and Ontology Mapping

1. INTRODUCTION

With the increasing importance of Electronic Commerce across the Internet, the need for software agents to support both customers and suppliers in buying and selling good/services is growing rapidly. It is becoming increasingly evident that in a few years the Internet will host a large number of interacting software agents. Most of them will be economically motivated, and will negotiate a variety of good and services. It is therefore important to consider the economic incentives and behaviors of ecommerce software agents, and to use all available means to anticipate their collective interactions. Even more fundamental than these issues, however, is the very nature of the various actors that are involved in Electronic Commerce transactions. The involved actors lead to different conceptualizations of the needs and capabilities, giving rise to semantic incompatibilities between them. It is hard to find two agents using precisely the same vocabulary. They usually have a heterogeneous private vocabulary defined in their own private ontology. This leads to different conceptualizations of the needs and capabilities, giving rise to semantic incompatibilities between them. This problem is referred to as the ontology problem of electronic negotiations (Viamonte and Silva, 2008).

Consequently, given the increasingly complex requirements of applications, the need for rich, consistent and reusable semantics, the growth of semantically interoperable enterprises into knowledge-based communities; and the evolution; the adoption of semantic web technologies need to be addressed (Silva and Rocha, 2004). In that sense, a suitable approach to address this interoperability problem relies on the ability to reconcile vocabulary used in agents' ontologies. In literature, this reconciliation problem is referred as Ontology Matching (Euzenat and Shvaiko, 2007).

In order to provide help in the conversation among different agents, we are proposing what we call ontology-services to facilitate agents' interoperability. More specifically, this work presents the AEMOS - Agent-Based Electronic Market with Ontology-Service System, a multi-agent market simulator with ontology services. The system includes agents that provide services that allow other agents to communicate with each other in order to reach an agreement, ensuring that both parties are able to understand the terms of negotiation.

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2. AEMOS SYSTEM

AEMOS system is an Agent Based Electronic Market where agents can customize their behaviors adaptively by learning each users preference model and business strategies.

Unlike traditional tools, agent based simulation does not postulate a single decision maker with a single objective for the entire system. Rather, agents representing the different independent entities in electronic markets are allowed to establish their own objectives and decision rules. Moreover, as the simulation progresses, agents can adapt their strategies, based on the success or failure of previous efforts.

AEMOS includes a complex simulation infrastructure; able to cope with the diverse time scales of the supported negotiation mechanisms and with several players competing and cooperating with each

other. In each situation, agents dynamically adapt their strategies, according to the present context and using the dynamically updated detained knowledge (Viamonte, Ramos, Rodrigues and Cardoso, 2006). AEMOS is flexible; the user completely defines the model he or she wants to simulate, including the number of agents, each agent's type, ontology and strategies. Figure 1, figure 2 and figure 3 shows the AEMOS System Interface.

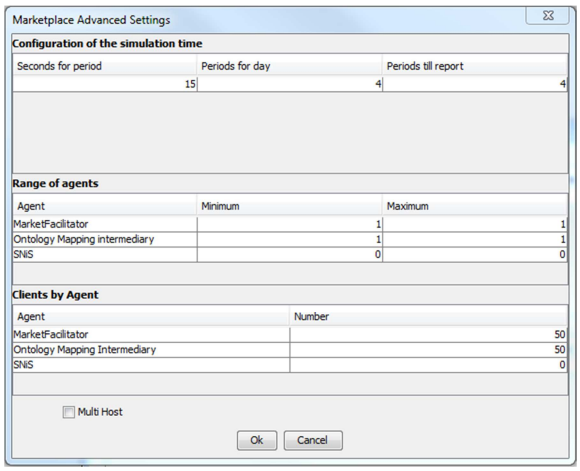

Figure 1: AEMOS system Interface – Internal Market Configuration

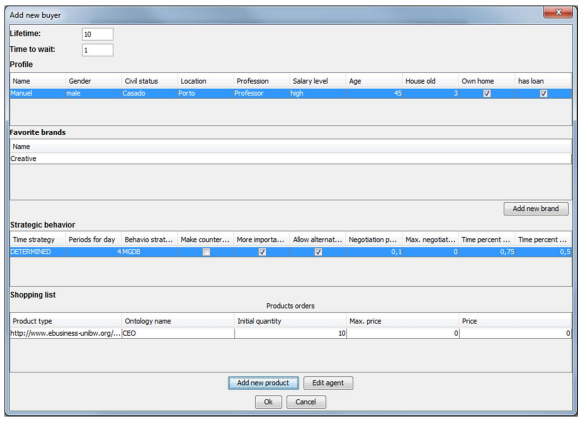

Figure 2: AEMOS system Interface – Buyer Configuration

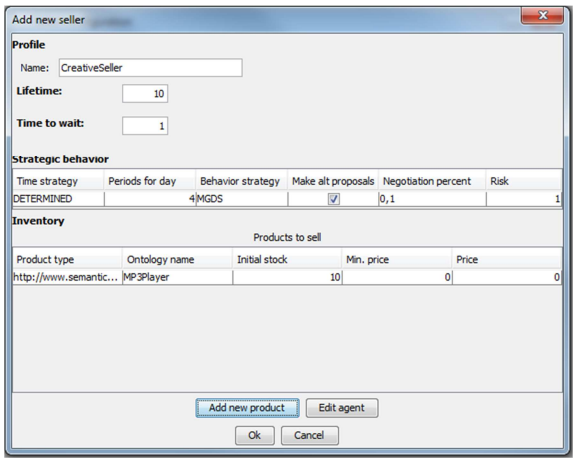

Figure 3: AEMOS system Interface – Seller Configuration

The simulator was developed based on "A Model for Developing a MarketPlace with Software Agents (MoDeMA)" (Viamonte, Ramos, Rodrigues and Cardoso, 2006). The following steps compose MoDeMA:

- Marketplace model definition, that permits doing transactions according to the Consumer Buying Behavior Model;
- Identification of the different participants, and the possible interactions between them;
- Ontology specification, that identifies and represents items on transaction;
- Agents architecture specification, and information flows between each agents module;
- Knowledge Acquisition, defining the process that guarantees the agent the knowledge to act on pursuit of its role;
- Negotiation Model, defining the negotiation mechanisms to be used;
- Negotiation Protocol, specification of each negotiation mechanism rules;
- Negotiation Strategies, specification and development of several negotiation strategies;
- Knowledge Discovery, identification and gathering of market knowledge to support agents' strategic behavior.

2.1. Multi-Agent Model

Multi-agent model includes three main types of actors as illustrated in figure 4.

Figure 4: AEMOS system layers

External Agents represent entities whose behavior is intended to be simulated and studied. There are two different types of external agents:

- Buyers (B) are agents representing entities desiring to acquire products;
- Sellers (S) are agents representing entities desiring to sell products.

Internal Agents provide services that allow external agents to communicate with each other in order to reach an agreement, ensuring that both parties are able to

understand the terms of negotiation. The main internal agents are:

- Market Manager (MM) is responsible for the market management. Manages all internal agents, register external agents and manages agents associations. In order to participate in the market an agent must first register with the MM agent. Usually there is only one MM agent per marketplace;
- Market Data Manager (MDM) registers information about all external agents participating in the market. When an external agent register in the market, the MDM agent collects its information, which is later provided when necessary. This agent is also responsible for writing statistical reports that enable to validate the correct functioning of the market. Normally there is only one MDM agent per marketplace;
- Market Facilitator (MF) is the agent responsible for the information integration process in the messages exchanged between external agents. It is an intermediate agent during the negotiation process that ensures, or tries to ensure that both parties are able to understand each other. Multiple MF agents can exist per marketplace. These agents are initialized by the MM agent when necessary. When an external agent is registered an MF agent is associated, from that moment all messages related to the negotiation process are sent for the associated MF;
- Ontology Matching intermediary (OM-i) is the agent that supports the information integration process. For that, this agent request the services (e.g. perform the information transformation according with the approved alignment) provided by several ontology matching specialized agents. Multiple OM-i agents can exist per marketplace, being initialized by the MM agent when necessary. When a MF agent is initialized an OM-i agent is associated, from that moment all the requests related to the information integration are sent to the associated agent.

2.2. Bilateral Contracts at AEMOS

In bilateral contracting B agents are looking for S agents that can provide them the desired products at the best price. We adopt what is basically an alternating protocol (Faratin, Sierra and Jennings, 1998).

Negotiation starts when a B agent sends a request for proposal. In response, a S agent analyses its own capabilities, current availability, and past experiences and formulates a proposal.

Seller's agents can formulate two kinds of proposals: a proposal for the product requested; or a proposal for a related product, according to the B agent preference model.

$PPg_{i\,Agts\rightarrow Agtb}^{DT}$ represents the proposal offered by the S agent $Agts$ to the B agent $Agtb$ at time T, at the negotiation period D for a specific product.

The B agent evaluates the proposals received with an algorithm that calculates the utility for each one, U_{PPgi}^{Agtb}; if the value of U_{PPgi}^{Agtb} for $PPg_{i\,Agts\rightarrow Agtb}^{DT}$ at time T is greater than the value of the counter-proposal that the B agent will formulate for the next time T, in the same negotiation period D, then the B agent accepts the offer and negotiation ends successfully in an agreement; otherwise a counter-proposal $CPg_{i\,Agtb\rightarrow Agts}^{DT}$ is made by the B agent to the next time T.

The S agent will accept a buyer counter-proposal if the value of U_{CPgi}^{Agts} is greater than the value of the counter-proposal that the S agent will formulate for the next timeT; otherwise the S agent rejects the counter-proposal.

On the basis of the bilateral agreements made among market players and lessons learned from previous bid rounds, both agents (B and S) revise their strategies for the next negotiation rounds and update their individual knowledge module.

3. THE ONTOLOGY-SERVICES MODEL

To provide a transparent semantic interoperability between all Electronic Commerce actors, an ontology-services infrastructure was added to AEMOS. Thus, the AEMOS system architecture recognizes three new types of actors:

- Ontology Matching Service (OM-s) agent is able to specify an alignment between two ontologies based on some ontology matching algorithm. There are several OM-s on the marketplace, each one providing the same service but based on distinct matching approaches (e.g. syntactic, lexical, structural);
- Ontology Matching Information Transformation (OM-t) agent is responsible to transform any information represented according to one ontology (i.e. source ontology) to a target ontology using an already specified alignment between those two ontologies. Multiple OM-t agents can exist per marketplace. When an OM-i agent is initialized an OM-t agent is associated, from that moment all the requests related to the information translation are sent to the associated agent;
- Ontology Matching Repository (OM-r) agent registers the agreed ontology alignments specified between agents' ontologies. These alignments are applied to enable further agents' interactions.

These actors deploy a set of complementary features among themselves whose goal is to automate and improve the quality of the results achieved in the

electronic commerce transactions. The OM-i agent is responsible to manage all these services and consequently to hide the resulting complexity of that task from the marketplace (namely from the MF agent).

Figure 5 depicts the types of interactions between the marketplace internal agents (i.e. MF and OM-i) and the external agents (i.e. B and S).

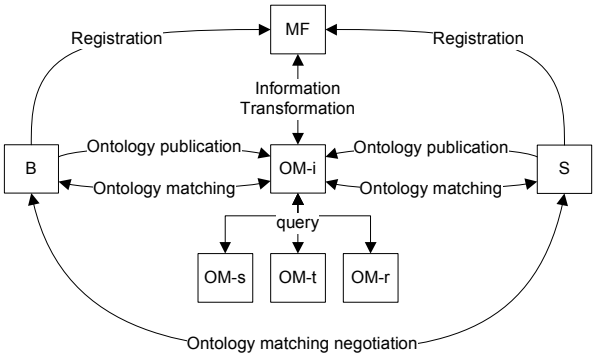

Figure 5: Marketplace actors and interactions

The Registration phase is initiated by the B or S agent and allows these agents to identify themselves to the marketplace and specify their roles and services.

The Ontology Publication phase is the set of transactions allowing B and S to specify their ontologies to the marketplace.

The Ontology Matching phase is the set of transactions driven by OM-i to align the ontologies of agents B and S. This phase is crucial for agents' interoperability and depends on the agents' ontology matching capabilities. By ontology matching (OM) capabilities of an agent we mean the ability it has to generate an alignment between two ontologies reflecting its own preferences and interests (e.g. alignment requirements), being such alignment achieved by its own or in cooperation with a set of ontology matching specialized agents (available or not in the marketplace). Yet, agents having OM capabilities may (or may not) have ontology matching negotiation (OMN) skills. Therefore, according to the agents' OM capabilities and OMN skills, for each pair of agents B and S six distinct scenarios are possible:

1. None of the agents' have OM capabilities;
2. Only one of the agents (say AgOM) have OM capabilities:
    a. AgOM do not have OMN skills;
    b. AgOM have OMN skills;
3. Both agents have OM capabilities:
    a. None of the agents have OMN skills;
    b. Only one of the agents have OMN skills;
    c. Both agents have OMN skills.

On the first scenario, the OM-i agent is fully responsible for the ontology matching task. Even though, OM-i agent may take into consideration a set of preferences about the ontology matching process specified by both agents. Therefore, OM-i generates a single alignment between agents' ontologies which need to be accepted by both agents.

On the other hand, on scenario 3c each agent generates its own alignment according to its internal preferences. Due to agents' different preferences and interests, the resulting alignments may have contradictory and inconsistent perspectives about candidate correspondences. Conflicts about correspondences are addressed by agents through the generic argumentation process described in (Maio, Silva, and Cardoso 2011a). In (Maio, Silva, and Cardoso 2011b) it is described how agents can exploit that argumentation process for ontology matching purposes. At the end, both agents need to inform the OM-i agent about the agreed alignment.

On scenarios 2a, 2b, 3a and 3b the agent lacking OM capabilities needs to delegate such responsibility to the OM-i agent. Yet, because the other agent has OM capabilities two distinct alignments exist. Resulting conflicts about correspondences are addressed either: (i) solely by OM-i agent if none of the agents have OMN skills (scenario 2a and 3a) or (ii) by a negotiation process between the agent with OMN skills and the OM-i agent in representation of the other agent (scenario 2b and 3b).

The Information Transformation phase is the set of information transactions through OM-i that transforms (i.e. converts) information described according to the sender's ontology to be described according to the receiver's ontology. This process is very methodical in accordance to the specified ontology alignment.

4. AN ONTOLOGY MAPPING EXAMPLE

For this example we consider a simple market with only two external agents (one B and one S).

The B agent intends to purchase 10 units of the same product (mp3 player) using for its representation the Ontology Consumer Electronics Ontology (CEO).

The S agent provides the desired product in sufficient quantity however uses for its representation the Ontology MP3Player (MP3_Player).

The interaction between agents is shown in Figure 6.

When MF receives a request for proposals for a product, as there are no S agents who use the same ontology as the B agent, MF makes a request to the OMi to suggest S agents that may be able to satisfy the request. OMi selects S agents that use some of the ontologies that can be mapped with the B agent's ontology. From this selection results a list of S agents (in this case only one) where for each S agent is associated a proposal for the mapping of its ontology with the B agent's.

Then the MF asks B and S agents for approval of the proposed mapping. If both approve, confirms the approval to OMi and ask him to represent the B request data according to the S ontology. The transformed data is replaced on the original request and it's forward to the S agent.

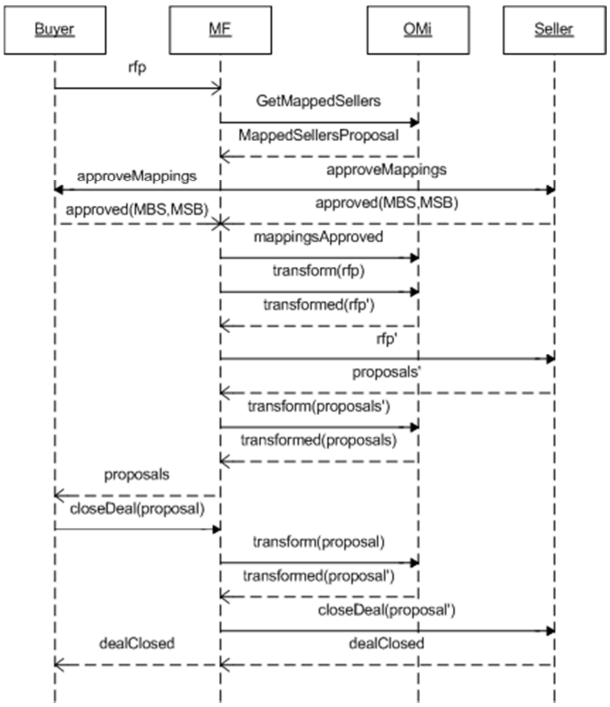

Figure 6: Data Integration Interaction

If the S formulates proposals, the MF makes a new request to the OMi so it represents the proposals data according to the B ontology.

During this process it's registered the approved mapping by the agents for the type of product. When a new communication is made by these agents related with this type of product (e.g. to close deal) the information is transformed using the approved mapping.

In case that the Players (B and S agents) don´t approved the ontology mapping proposed by the system an Ontology Matching Negotiation Process (Maio, Viamonte and Silva, 2011) is used in order to obtain an agreement. It is envisaged that in the ontology matching negotiation phase agents adopt the argument-based negotiation process presented in (Maio, Viamonte and Silva, 2011).

In real scenarios with more Players (B and S agents) the process descripted above is replicated.

5. IMPLEMENTATION

The AEMOS system was developed in Open Agent Architecture (OAA) (http://www.ai.sri.com/~oaa/) and in Java.

The OAA platform, figure 7, is a framework for integrating a community of heterogeneous software agents in a distributed environment. It is structured to minimize the effort involved in creating new agents, written in various languages and operating platforms; to encourage the reuse of existing agents; and to allow the creation of dynamic and flexible agent communities. The OAA's Interagent Communication Language is the interface and communication language shared by all agents, no matter which machine they are running on or which programming language they are programmed in. OAA is not a framework specifically devoted to develop simulations; some extensions were made to make it more suitable, such as the inclusion of a clock to introduce the time evolution mechanism of the simulation.

Each agent is implemented in Java, as a Java thread. The model can be distributed over a network of computers, which is a very important advantage to increase simulation runs for scenarios with a huge amount of agents.

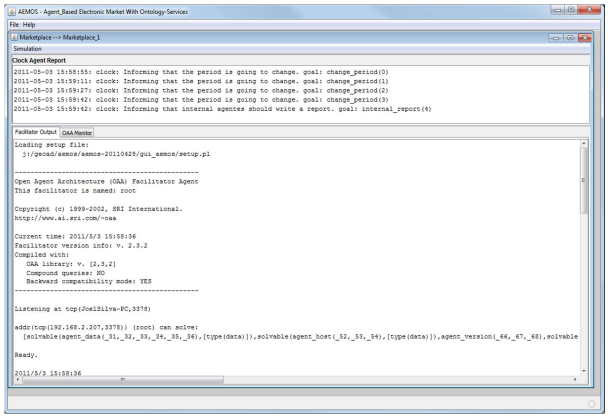

Figure 7: The OAA Facilitator

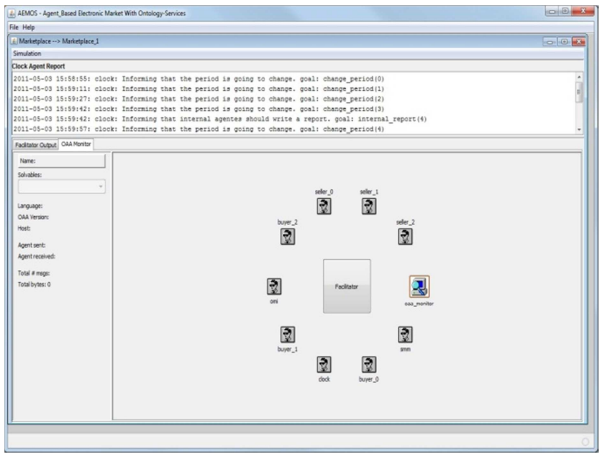

Figure 8: The AEMOS MarketPlace

6. CONCLUSIONS

AEMOS project is an innovative project that proposes a semantic information integration approach for agent-based electronic markets based on ontology-based technology, improved by the application and exploitation of the trust relationships captured by the social networks.

We intent face the problem of the growth of electronic commerce using software agents to support both customers and suppliers in buying and selling products. The diversity of the involved actors leads to different conceptualizations of the needs and capabilities, giving rise to semantic incompatibilities between them.

Ontologies have an important role in Multi-Agent Systems communication and provide a vocabulary to be used in the communication between agents. It is hard to find two agents using precisely the same vocabulary. They usually have a heterogeneous private vocabulary defined in their own private ontology. In order to provide help in the conversation among different agents, we are proposing what we call ontology-services to facilitate agents' interoperability. More specifically, AEMOS project proposes an ontology-based information integration approach, exploiting the ontology mapping paradigm, by aligning consumer needs and the market capacities, in a semi-automatic mode, improved by the application and exploitation of the trust relationships captured by the social networks.

Yet, it is our conviction that the marketplace must encourage agents to play an important role in the required matching process. Even though, that cannot be a mandatory issue and therefore the marketplace must be equipped to deal with agents having different ontology matching capabilities. It is envisaged that by taking part in the matching process agents may become more confident in the underlying communication process and in face of that consider the electronic commerce exchanged data (e.g. RFP and PP) more reliable (safe) and consequently become more proactive in the marketplace.

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(MP3_Player) MP3_ Player. Available from: http://daisy.cti.gr/svn/ontologies/AtracoProject/AtracoUserProfile/Y2Integration-FeelComfortable/MP3_Player.owl

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