AEMOS: AN AGENT-BASED ELECTRONIC MARKET SIMULATOR WITH ONTOLOGY-SERVICES AND SOCIAL NETWORK SUPPORT

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ABSTRACT

In E-commerce environments software agents are used in automated negotiations. When agents communicate they do not necessarily use the same vocabulary or ontology. However, if they want to interact successfully they must find correspondences between the terms used in their ontologies. This paper proposes to enhance agent-based electronic markets with a set of ontology-services to facilitate communication between agents. However, humans tend to be reluctant to accept other's conceptualizations/ontologies. For that they must be convinced that a good deal can be achieved. In this context, the application and exploitation of trust relationships captured by social networks can result in the establishment of more accurate trust relationships between businesses and customers, as well as the improvement of the negotiation efficiency.

Keywords: agent based simulation, electronic markets, ontology mapping negotiation, social network analysis

1. INTRODUCTION

In an efficient agent-mediated electronic market, where all the partners, both sending and receiving messages have to lead to acceptable and meaningful agreements, it is necessary to have common standards, like an interaction protocol to achieve deals, a language for describing the messages' content and ontologies for describing the domain's knowledge (Hepp, 2008) (Fensel, et al., 2001) (Obrst, et al., 2003).

The need for these standards emerges due to the nature of the goods/services traded in business transactions. The goods/services are described through multiple attributes (e.g. price, features and quality), which imply that negotiation processes and final agreements between sellers and buyers must be enhanced with the capability to both understand the terms and conditions of the transaction (e.g. vocabulary semantics, currencies to denote different prices, different units to represent measures or mutual dependencies of products).

In order to provide an answer for this need we developed the AEMOS system - Agent-Based Electronic Market with Ontology-Service System, a multi-agent market simulator with ontology services. The AEMOS system is an innovative project (PTDC/EIA-EIA/104752/2008) supported by the Portuguese Agency for Scientific Research (FCT).

The system 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.

In this paper we give a brief introduction to the AEMOS system model (Section 2) detailing the Ontology Services component (Section 3). We then present the social network component (Section 4) illustrating how agents exploit social network information in combination with the meta information captured during the agent's business interactions.

2. AEMOS SYSTEM

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, et al., 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, ontologies and strategies. This infrastructure is detailed in (Viamonte, et al., 2011).

2.1. Multi-Agent Model

The model includes several types of agents divided into two main groups namely, external agents and internal agents. The external agents are agents whose behavior is intended to be simulated and studied. The main types of external agents are: Buyers (B) who are agents representing consumers; and Sellers (S) who are agents representing suppliers.

The internal agents are the ones who support the communication and negotiation between external agents. The main internal agents are: the Market Facilitator (MF) that is responsible for the information integration process in the message exchange 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; the Ontology Mapping Intermediary (OM-i) that is responsible for the ontology mappings' management and for the ontology's instances translation process. This agent is able to propose ontology mappings and to translate ontology's instances when requested; and the Social Network Intermediary (SN-i) that is the agent responsible for the discovery of agents' trust (or proximity) relations captured through social network analysis techniques applied on the market information. This agent is able to support the OM-i agents on their tasks and to advise external agents about proposed ontology mappings or negotiating partners.

In other to participate in the market, an external agent must register first, indicating the ontologies it uses and, optionally, its personal data and preferences.

2.2. The Negotiation Model

The negotiation protocol used in AEMOS is bilateral contracting where B agents are looking for S agents that can provide them with the desired products at the best conditions.

Negotiation starts when a B agent sends a request for proposal (RFP). In response, a S agent analyses its own capabilities, current availability, and past experiences and formulates a proposal (PP). On the basis of the bilateral agreements made among market players and lessons learned from previous bid rounds, both agents revise their strategies for the next negotiation round and update their individual knowledge module.

The negotiation protocol has three main actors: B agents, S agents and MF agent. Both agents, B and S may seek advice with a SN-i agent in order to decide about the acceptance/formulation of a proposal.

When a deal is closed, the B agent is expected to perform the payment, and the S agent the delivery, according to the CBB model (Runyon & Stewart, 1987). Then, when the transaction is completed, both agents are invited to evaluate the whole process (i.e. rate the negotiation partner and, if it's the case, the used ontology mappings).

If some agent frequently fails to close a deal or perform the payment or delivery, the negotiating partner can express its dissatisfaction with the agent, sending a declaration of depreciation with the agent's behavior to the MF agent. On the other hand, if an agent has a history of satisfactory interactions with another agent, it can express its satisfaction by sending a declaration of appreciation with the agent's behavior to the MF agent.

3. THE ONTOLOGY-SERVICES COMPONENT

To provide a transparent semantic interoperability between all e-commerce actors, AEMOS has an ontology-services infrastructure whose system architecture recognizes three new types of actors: the Ontology Matching Service (OM-s) agent that 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 (Euzenat & Shvaiko, 2007); the Ontology Matching Information Transformation (OM-t) agent that is responsible for transforming any information represented according to one ontology (i.e. source ontology) to information represented according to a target ontology, using an already specified alignment between those two ontologies; and the Ontology Matching Repository (OM-r) agent that registers the agreed ontology alignments specified between agents' ontologies. These alignments are applied to enable further agents' interactions.

These actors deploy a set of relationship types whose goal is to automate and improve the quality of the results achieved in the e-commerce transactions.

3.1. The Integration Protocol

Considering the previous descriptions, a more complete and complex protocol is now detailed, including the OM-i and SN-i agents in the system, Figure 1.

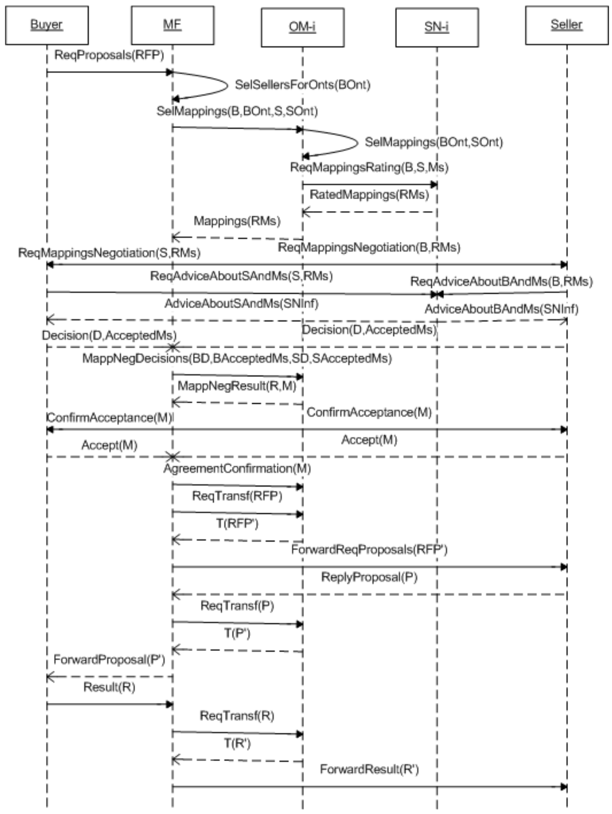

Figure 1: The Integration Protocol

The integration starts when a B agent sends a request for proposal message to the MF agent. In response, the MF tries to find possible S agents for the request by selecting the ones using the same ontology as the B agent or an ontology with known correspondences.

When B and S use different ontologies the OM-i starts the ontology mapping specification process, with the support of other entities, including matching agents, ontology mapping repositories and SN-i. SN-i is responsible for retrieving the relevant information from ontology mapping repositories and social networks. Past similar ontology mapping experiences undertaken by agents with trust relationships with B and S will be used by SN-i to compile the social network repository information. Because the request for this information is the exclusive responsibility of OM-i, both B and S are advised to perform a similar verification (eventually using other SN-i) once the ontology mappings are submitted for negotiation.

At the ontology mapping negotiation, both B and S decide about their interest in negotiating with the proposed partner and the ontology mappings that are preferred. The decisions are sent to the OM-i who will check for a possible agreement. If an agreement is found both B and S are required to confirm their acceptance.

Despite the fact that Figure 1 represents only the acceptance scenario, a rejection scenario is also possible, in which case no further interaction will occur between B and S. In case the mapping is accepted, MF resumes the protocol by requesting to OM-i the RFP data transformation. Using the ontology mapping document, RFP data represented according to B's ontology is transformed into data represented according to S's ontology. The transformed data (RFP') is forwarded to S, which will process it and will reply to MF. MF will then request the transformation of the proposal data (P) and will forward the transformed proposal (P') to B. B processes it and will accept or formulate a counterproposal (CP). As illustrated, once a mutually acceptable ontology mapping is established between B's ontology and S's ontology, all messages exchanged between B and S through MF are forwarded to OM-i for transformation.

Notice that Figure 1 represents one single S agent in the system, but in fact multiple S agents capable of replying to the request may exist in the marketplace. In such case, the system would replicate the previous protocol for as many capable S agents.

4. THE SOCIAL NETWORK COMPONENT

During the simulation, information about the market, its participants and their interactions is collected and maintained. This information is then provided to SN-i agents who apply social network analysis techniques (Wasserman & Faust, 1994) in order to capture proximity relations between agents. This knowledge allows the improvement of the market's functioning by supporting agents on their decisions.

4.1. Relationship Graph Building

A SN-i agent starts by building the agent's relationship graph by comparing each agent to all others, determining the existence and intensity of relations between pairs of agents. For each pair of agents, the SN-i evaluates:

- The similarity between their attributes (normally, personal data or preferences provided during the registration phase);
- The similarity of their actions (rating ontology mappings, rating other agents, declarations about other agents);
- The existence of appreciation relations between them (relation that exists when one of the agents declared appreciation or depreciation with the other's behavior).

The intensity of the relationship between the pair of agents results from the weighted average of the values obtained for each of these evaluations.

4.1.1. Agents' Attributes Similarity Evaluation

To evaluate the similarity of attributes, the SN-i extracts properties of the information provided by both agents during their registration on the market, normally personal data and preferences. There are different types of properties that can be characterized by the type of value, namely discrete (e.g. marital status) or continuous (e.g. age), and the number of times they can be declared by an agent, namely functional (only one, e.g. marital status) or non-functional (e.g. trusted community).

The value of similarity for a continuous property can be obtained by (Wu, et al., 2007):

$$contPropEval(a,b,p) = 1 - \frac{|p(a)-p(b)|}{\max(p)-\min(p)} \qquad (1)$$

Where a and b are the analyzed agents, p is the evaluated property, $p(a)$ and $p(b)$ are the values of the property p for agents a and b respectively, $max(p)$ is the maximum limit for property p and $min(p)$ is the minimum limit. Following the same conventions, now with $p(a)$ and $p(b)$ representing the set of values of the property p for agents a and b respectively, the similarity value of a discrete functional property is given by (Luz, 2010):

$$discFuncPropEval(a,b,p) = \begin{cases} 1: |p(a) \cap p(b)| > 0 \\ 0: otherwise \end{cases} \qquad (2)$$

The similarity value of a non-functional discrete property is given by (Luz, 2010):

$$discNonFuncPropEval(a,b,p) = \frac{|p(a) \cap p(b)|}{|p(a) \cup p(b)|} \qquad (3)$$

SN-i will compare each property that is declared for both agents. The result of this evaluation is obtained by averaging all calculated values.

4.1.2. Agents' Actions Similarity Evaluation

For the evaluation of similarity of agents' actions, the SN-i considers the following actions: (i) rating an ontology mapping; (ii) rating an agent; and (iii) declaring appreciation/depreciation with an agent's behavior. SN-i starts by checking if both agents performed the same type of action over the same market's element (ontology mapping or agent), and if so, checks if they performed it in a similar way (e.g. if both agents gave a positive rating to a determined agent).

For this evaluation it is applied a similar approach to the one used for non-functional discrete properties, considering as a property an action performed over some market's element. SN-i will calculate the similarity of each action performed over the same element and then the final value of this evaluation is obtained by averaging all calculated values.

4.1.3. Agents' Appreciation Relations

The appreciation relations correspond to the declaration of appreciation or depreciation with an agent's behavior. The agent includes a value in this declarations that determines if it's a declaration of appreciation (positive value), or depreciation (negative value), and its intensity (e.g. a high negative value represents a high level of dissatisfaction). The result of the evaluation of appreciation/depreciation relations corresponds to the average of the values attributed in the declarations. If no relation exists the value is zero.

4.1.4. Resultant Relationship Graph

SN-i obtains a value for each of the three evaluations mentioned above (Sections 4.1.1, 4.1.2 and 4.1.3), and the relationship intensity value corresponds to the weighted sum of these values.

After repeating the process for all pairs of agents a relationship graph is obtained, where each node represents an agent and each edge represents a relation between two agents. The resultant graph is directed, weighted and signed, meaning that each relation is directed (not bidirectional), has an intensity value associated which might be positive or negative.

The graph is updated when new information is provided and is consulted when necessary.

4.2. SN-i Functionalities

As illustrated in Figure 1, an SN-i agent may receive two types of requests:

- Request to evaluate a set of ontology mappings for a pair of agents: in Figure 1, request *ReqMappingsRating(B,S,Ms)*, where *Ms* corresponds to the list of ontology mappings to evaluate for a given pair of agents, namely *B* and *S* agents;
- Request to advise an external agent about the use of an ontology mapping and/or the negotiation with a proposed partner: in Figure 1, requests *ReqAdviceAboutSAndMs(S,RMs)* and *ReqAdviceAboutBAndMs(B,RMs)*, where *RMs* is the list of ontology mappings to evaluate for the agent that performed the request, and *S* and *B* correspond to the agents that should be evaluated.

In order to fulfill these requests, the SN-i should be able to:

- Determine the confidence value of the proposed ontology mapping for an agent, or pair of agents;
- Determine the level of trust that an agent should have with the proposed negotiating agent.

4.2.1. The Confidence Value of an Ontology Mapping for an Agent

The confidence value of an ontology mapping (*M*) for an agent *a* is obtained considering the (i) evaluation of the ontology mapping information taking into account the agent's preferences (*mapInfoEval(a,M)*), (ii) the ratings of the ontology mapping given by agents that have a relationship with the analyzed agent (*relAgtsRateEval(a,M)*) and (iii) the rating given by the agent itself (*rate(a,M)*):

$$mappingTrustValue(a,M) = \alpha.mapInfoEval(a,M) + \beta.relAgtsRateEval(a,M) + \gamma.rate(a,M) \quad (4)$$

where α, β and γ are the weights attributed to each evaluation.

For the evaluation of the ontology mapping information a simple approach is followed:

$$mapInfoEval(a,M) = \delta.mapMetricsEval(M) + \varepsilon.prevPerformanceEval(M) + \zeta.relEntitiesEval(a,M) + \eta.valuedPropEval(a,M) \quad (5)$$

where δ, ε, ζ and η are the weights attributed to each evaluation, and:

- The ontology mapping metrics, i.e. *mapMetricsEval(M)*, is given by the percentage of covered concepts and properties of the agent's ontology, and the average percentage of properties mapped by concept:

$$mapMetricsEval(M) = mappedConceptsPercent(M) + mappedPropertiesPercent(M) + avgMapPropByConceptPercent(M) \quad (6)$$

- The previous performances of the ontology mapping, i.e. *prevPerformanceEval(M)*. In this case some historic information about the prior usage of the ontology mapping, namely the average loss of information during the transformation process (*avgLossInfo(M)*), can be considered:

$$prevPerformanceEval(M) = 1 - avgLossInfo(M) \quad (7)$$

- The ontology mapping related entities (i.e. the communities responsible for its creation and maintenance) comparing with the ones the agent trust. *relEntitiesEval(a,M)* is given by the sum of the weight attributed by the agent to the trusted entities that are related to the mapping (*CE(a,M)*, meaning common entity between *a* and *M*). This value is then divided by the sum of the weights of all entities that the agent trusts (*TE*). If no weight is attributed it is considered to be 1:

$$relEntitiesEval(a,M) = \frac{\sum weight(a,CE(a,M))}{\sum weight(a,TE)} \quad (8)$$

- The ontology's concepts or properties covered by the mapping, comparing with the ones valued by the agent, i.e. *valuedPropEval(a,M)*. It is given by the sum of the weights attributed by the agent to the properties/concepts that are both valued by the agent and covered by the mapping (*CP(a,M)*), divided by the sum of the weight of all properties/concepts valued by the agent (*VCP*):

$$valuedPropEval(a,M) = \frac{\sum \mathrm{weight}(a,CP(a,M))}{\sum \mathrm{weight}(a,VCP)} \quad (9)$$

To evaluate the ratings given by related agents, the SN-i consults the relationship graph, selecting the agents with closest relations (i.e., relations with higher positive value) with the analyzed agent who rated the ontology mapping. The SN-i can continue searching the graph for related agents until the obtained information is considered sufficient. The value of the analysis is given by the average of the ratings (*rate*) made by the related agents (*RA*), weighted by the intensity of its relation to the agent (*relVal*).

$$relAgtsRateEval(a,M) = \frac{\sum_{b \in RA} \mathrm{relVal}(a,b).\mathrm{rate}(b,M)}{\sum_{b \in RA} \mathrm{relVal}(a,b)} \quad (10)$$

By considering the information about the ontology mapping, and not only the evaluations made by the related agents, the cold start problem (a typical problem of collaborative recommendation systems that rises when an item, here an ontology mapping, has no previous evaluations) does not occur. The historic information about ontology mapping's performance, namely average loss of information during the transformation process, enables a fair comparison between those ontology mappings that contemplate only a relatively small part of an ontology (that in the current context is usually the only part that is relevant) with those who have a higher coverage but the same relevant parts.

4.2.2. The Confidence Value of an Ontology Mapping for a Pair of Agents

When SN-i receives a request to evaluate a set of ontology mappings for a pair of agents, the process described above (Section 4.2.1) is repeated for each mapping for each of the two agents, i.e., for a pair of agents, namely agent *a* and agent *b*, SN-i calculates the confidence value of each mapping *M* for agent *a* (*mappingTrustValue(a,M)*) and for agent *b* (*mappingTrustValue(b,M)*), and the confidence value of the mapping *M* is obtained by averaging the calculated values:

$$mappingTrustValue(a,b,M) = (mappingTrustValue(a,M) + mappingTrustValue(b,M)) / 2 \quad (11)$$

4.2.3. The Level of Trust an Agent Should Have with another Agent

The level of trust that an agent should have with another (confidence value of the relation) is determined in a similar way to the previously described for the ontology mapping. In this case the SN-i considers the ratings that the agents closest to the one that performed the request gave to the agent that is being analyzed (*relAgtsAgtEval*) and the one given by the agent itself (*rate*). It also considers the existence and intensity of a relation between the requester and the analyzed agents (*relVal*). The metric can be represented as:

$$agentTrustValue(a,b) = \lambda.relVal(a,b) + \mu.relAgtsAgtEval(a,b) + \sigma.rate(a,b) \quad (12)$$

where *a* is the agent that performed the request, *b* is the agent being analyzed, and λ, μ and σ are the weights attributed to each component. The evaluation of the related agents' ratings of agent *b* can be obtained by:

$$relAgtsAgtEval(a,b) = \frac{\sum_{c \in RA} \mathrm{relVal}(a,c) * \mathrm{rate}(c,b)}{\sum_{c \in RA} \mathrm{relVal}(a,c)} \quad (13)$$

When an agent seeks advice about another, some information like (i) the tendency of the agent's ratings (i.e. if the rates given by other agents are stable, increasing or decreasing), (ii) the agent's prestige (obtained through the analysis of its positive relations), and (iii) the agent's global and local satisfaction (obtained through the analysis of the transactions' negotiation both with the requester agent and with all agents) can be very important, and should be provided as additional information about the agent.

Some evaluations (represented by equations 4, 5 and 12) have weights associated to each component that allows differentiating its relevance to the final value. These weights are defined by the user at the simulation configuration.

5. CONCLUSIONS

New generation of e-commerce applications allows e-commerce actors (represented by software agents) to adopt different ontologies to describe their universe of discourse, their needs and their capabilities, raising an heterogeneity problem that is seen as a corner stone for interoperability, namely for communication. Therefore, to achieve a consistent and compatible communication, agents need to reconcile their vocabularies, through an ontology matching process, resulting in the alignment of their ontologies. While in several domains of application the alignment specification can be done in design-time, e-commerce scenarios require that alignment specification is done in run-time since e-commerce actors have no prior knowledge of the other actors with whom they will interact.

AEMOS relies on the conviction that the marketplace must provide a technological framework promoting and enabling the semantic integration between parties through the use of ontology matching. 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 e-commerce exchanged data (e.g. RFP and PP) more reliable (safe) and consequently become more proactive in the marketplace.

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