Agent-based Electronic Commerce with Ontology Services and Social Network based Support

Virgínia Nascimento, Maria João Viamonte, Alda Canito and Nuno Silva
[1]GECAD, Knowledge Engineering and Decision Support Research Center, Institute of Engineering, Polytechnic of Porto (ISEP/IPP), Porto, Portugal

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Abstract: In this paper we approach the semantic heterogeneity problem which arises in agent mediated electronic commerce, presenting the AEMOS system as a promising answer. AEMOS is an agent mediated electronic commerce platform which main goal is to enable an efficient and transparent negotiation between agents even when they use different ontologies to represent the same domain of knowledge. The system provides ontology services, more specifically ontology matching services, which are improved by the exploitation of emergent social networks. In this paper we present the currently implemented system and demonstrate how an agent mediated electronic commerce system may benefit from the inclusion and combination of ontology services and social network based support.

1 INTRODUCTION

Electronic commerce (e-commerce) is a widely used technology with an increasing popularity in today's business (Du et al., 2005). In this type of commerce the information becomes more easily available, increasing the possibility of achieving more satisfactory deals. However, the amount of available information also becomes a problem, being difficult for a human user to compare all possible deals in order to achieve the best one.

Intelligent agents present characteristics that make them a powerful tool to overcome this problem. However, the diversity of the available information, which is normally represented for human comprehension only, turns the development of fully automated systems into a challenge.

In order to overcome this problem, ontology centered approaches have been proposed (Mei et al., 2009, Cao et al., 2009) and e-commerce key players such as Google, Yahoo, Amazon and O'Reilly are progressively supporting these through micro-formats, micro-data and RDFa (O'Brien, 2009).

However, given the natural diversity of such an open and accessible environment, the involved entities may possess different conceptualization about their needs and capabilities, giving rise to a semantic heterogeneity problem that is seen as a corner stone for agents' interoperability.

Based on these issues we developed AEMOS – Agent-based Electronic Market with Ontology Services (Nascimento et al., 2012, Viamonte et al., 2012, Viamonte et al., 2011, Silva et al., 2009), an innovative project (PTDC/EIA-EIA/104752/2008) supported by the Portuguese Agency for Scientific Research (FCT).

The main goal of this project is to provide an agent mediated e-commerce (AMEC) platform capable of enabling an efficient and transparent negotiation between agents even when they use different ontologies, ensuring that they are able to understand each other and correctly assess the terms and conditions of each transaction. For that we follow an ontology based information integration approach, exploiting the ontology matching paradigm (Euzenat and Shvaiko, 2007), which is improved by the application and exploitation of emergent social networks (SN).

During the development of this project different models have been proposed and tested, e.g. see (Nascimento et al., 2012, Viamonte et al., 2012, Viamonte et al., 2011, Silva et al., 2009). In this paper we present the currently implemented system, clarifying the fundaments leading to our choices, and presenting the more recently achieved results.

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We start by briefly describing the research background (Section 2). Then we present an overview of the AEMOS system (Section 3), highlighting the implemented ontology services (Section 4) and SN-based support (Section 5). In order to assess our proposal we present details about the AEMOS prototype and describe some experiments analyzing the achieved results (Section 6). Finally we draw some conclusions and suggest follow-up research efforts (Section 7).

2 BACKGROUND

The most frequent approaches for AMEC systems consider simplified and limited solution in order to avoid semantic problems. Some consider the existence of a commonly agreed ontology, such that to participate in the market each agent has to adopt this ontology, e.g. (Viamonte et al., 2007). Other approaches, consider the existence of different ontologies, but only allow communication between agents that use the same ontology, e.g. (Cui-Mei, 2009).

The Foundation for Intelligent Physical Agents (FIPA) has analyzed the interoperability problem in heterogeneous multi-agent systems (MAS) and has proposed the introduction of an agent that, among other responsibilities, would be capable of translating expressions between different ontologies (FIPA, 2001). An implementation of such an agent is proposed in (Briola et al., 2008), where the translation service is achieved through ontology matching.

Ontology matching (Euzenat and Shvaiko, 2007) can be described as the process of discovering semantic relations (i.e. correspondences) between the concepts and properties of two ontologies. The discovered relations are represented in an ontology alignment document so they can be applied in data transformation.

There are already some approaches for AMEC systems which include ontology matching services in order to solve semantic problems. Some examples are the models presented in (Malucelli et al., 2006) and in (Wang et al., 2010). However, each approach tends to focus on a particular aspect or phase of the known behavior models, and often ignore the effect that the complexity of the matching processes can have in the communications' efficiency.

Ontology matching is a naturally ambiguous and subjective process, leading to different alignments that may be more or less adequate to each negotiation and therefore influence its efficiency and result. The quality and adequacy of an ontology alignment is very important in the negotiation, since it may determine the efficiency of the interaction. For example, a consumer may request a product that a supplier has on its inventory, but by using an inadequate alignment, relevant information may be lost during the transformation process causing the supplier not to be able to match it.

On the other hand, detecting incorrect or inadequate ontology alignments is not a trivial task. A negotiation may fail because the alignment is inadequate to the current context, but it can also fail simply because the supplier does not have the desired products, or even because the agents have different goals (e.g. conflicting prices).

3 AEMOS SYSTEM OVERVIEW

The AEMOS system is based on ISEM (Viamonte et al., 2007), which is an agent-based simulator system for e-commerce, originally developed for studying agents' market strategies. In reality, AEMOS is an evolution of the ISEM system, keeping all its original functionalities, but allowing agents to use different ontologies.

AEMOS provides ontology services in order to enable negotiation between agents that use different ontologies. The system exploits the ontology matching paradigm (Euzenat and Shvaiko, 2007), selecting and suggesting possible alignments between the agents' ontologies, and letting the agents choose which one should be used to translate the subsequent exchanged messages.

In order to overcome issues related to how the chosen ontology alignment may influence the business negotiation efficiency, the relevance of social network analysis (SNA) (Wasserman and Faust, 1994) in recommending ontology alignments for e-commerce negotiations is claimed, by including in the system a SN-based support component, capable of improving the ontology alignments recommendations and supporting the agents' decisions about which alignment to choose.

3.1 Multi-Agent Model

The AEMOS multi-agent model, illustrated in Figure 1, includes several types of agents classified in two main categories, namely: the business agents and the supporting agents.

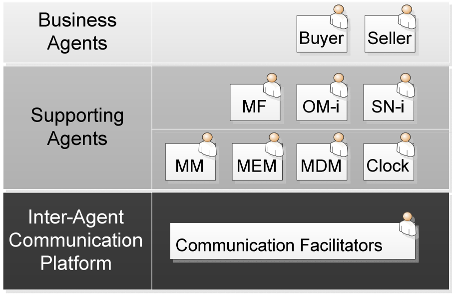

Figure 1: AEMOS multi-agent model.

The business agents represent real world entities, which possess business goals to be satisfied. These agents are highly customizable and dynamic. In each situation, they adapt their strategies, according to the present context and based on their updated knowledge (Viamonte et al., 2007). Currently two types of business agents are considered, namely:

- Buyer (B) – agent representing a consumer, i.e., an entity, normally a person wishing to acquire a set of products;
- Seller (S) – agent representing a supplier, i.e. an entity, usually a company wishing to sell a set of products.

The supporting agents are those providing services that allow business agents to carry transactions with each other in order to satisfy their goals. This category can be further divided in two groups, namely: the service intermediary agents and the system management agents.

The service intermediary agents support the business agents, providing services that enable an efficient interoperability between them. In this category are the agents:

- Market Facilitator (MF) – agent that coordinates the interaction between business agents, being responsible for ensuring that the communicating agents are able to understand each other. When a B agent is registered, a MF agent is associated; from that moment on, all messages related to the business negotiation process pass through the associated MF agent;
- Ontology Matching intermediary (OM-i) – agent responsible for the ontology services, recommending possible ontology alignments for each business negotiation, and transforming the exchanged messages according to the agreed alignment. When a MF agent is initiated an OM-i agent is associated; from that moment on, all the requests related to ontology matching services are sent to the associated OM-i agent;
- Social Network intermediary (SN-i) – agent responsible for the SN-based support, providing advice about the adequacy of the ontology alignments to each business negotiation. When an OM-i agent is initiated, or a business agent registers in the market, a SN-i agent is associated; from that moment on, all requests related to SN-based support are sent to the associated SN-i agent.

Normally there are multiple agents of these types per marketplace, being initialized when necessary.

The system management agents are responsible for granting the system's dynamism, flexibility and correct functioning. In this category are the agents:

- Market Manager (MM) – agent responsible to manage all supporting agents and to register business agents so they can participate in the market. Normally there is only one agent of this kind per marketplace;
- Market Extension Manager (MEM) – agent that aids the MM on its functions, allowing the dynamic addition of machines where supporting agents may be initialized. The presence of this kind of agent is optional, although normally there are multiple agents of this type per marketplace;
- Market Data Manager (MDM) – agent that collects and maintains information about the market participants and their activities, writing statistical reports which allow evaluating the system's performance. Normally there is only one agent of this type per marketplace;
- Clock – agent that simulates the evolution of time, notifying the appropriate agents about periodic (or scheduled) events. Normally there is only one agent of this type per marketplace.

In addition to these types of agents there are the Communication Facilitator agents, which are responsible for establishing communications between the different agents of the system. Since our system is based in OAA (OAA, 2001), this role is played by the Facilitator agent provided by this platform.

3.2 Interaction Protocol

To participate in the market, the business agents must register first, providing information about the ontologies that they use, and sharing (parts of) the profile of the entity they represent. This information is stored by MF and SN-i agents. Once registered, the agents are allowed to negotiate. For that, B agents start announcing their buying products and wait for S agents to formulate proposals. Figure 2 illustrates the interactions between the main intervenient during a business negotiation.

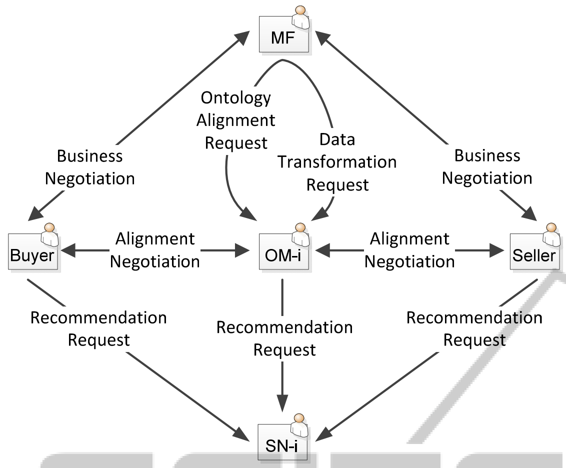

Figure 2: General agents' interaction.

When the negotiation starts, the responsible MF selects the S agents that might be able to satisfy the B agent's request. For that it follows an ontology-based approach, selecting: (i) the S agents that use the same ontology as the B; and, (ii) supported by an OM-i, the ones that use ontologies that can be aligned with it. Therefore, the business negotiations may occur in two different scenarios:

- A scenario where both agents use the same ontology – the MF acts as a proxy between B and S, simply receiving and forwarding messages;
- A scenario where the agents use different ontologies – it is necessary to find an agreement about the alignment between the respective ontologies that should be used to translate the exchanged messages. For that the MF requests an OM-i to mediate an ontology alignment negotiation between B and S. If an agreement is achieved, the subsequent exchanged messages are sent to the OM-i, which translates their content according to the agreed alignment ensuring that the message receiver will be able to understand it.

During the business negotiation the involved agents, B and S, exchange proposals and counterproposals, following a protocol based on the FIPA's "Iterated Contract Net Interaction Protocol Specification" (FIPA, 2002), terminating the negotiation when an agreement is achieved or when they have no more proposals to formulate.

When a business agent satisfies all its business goals, or its deadlines are reached, it must terminate its activity, notifying the market and declaring the achieved results.

3.3 Ontology Alignment Negotiation Protocol

The ontology alignment negotiation initiates when a MF sends a request to an OM-i identifying (i) both agents, (ii) the respective ontologies and (iii) providing information about the B agent's request.

The OM-i selects, from its repository, all the possible alignments between the indicated ontologies. Then, it performs sorting and filtering actions, following its internal criteria and/or requesting a SN-i to rank the alignments, obtaining a list of possible alignments and their respective score. Both B and S, analyze the recommended alignments taking into account their preferences, replying to the OM-i with the list of the alignments which they consider acceptable.

The OM-i analyzes both replies and checks if there is an agreement, i.e., if some alignment was selected by both agents. If there is no agreement, depending on the system configuration, the negotiation may terminate, or proceed, with the OM-i refining its list of recommended alignments and asking agents to reconsider their options and criteria. Otherwise, if there is an agreement, the OM-i notifies both agents and the MF about the agreement and proceeds with the transformation of the B agent's request. From that moment on, all the subsequent exchanged messages between the agents are forward to the OM-i for transformation.

4 ONTOLOGY SERVICES

The ontology services are provided by OM-i agents. An OM-i is responsible for (i) discovering ontologies and ontology alignments, (ii) providing information about ontologies and alignments, (iii) proposing alignments for negotiation, (iv) coordinating alignment negotiations, and (v) transforming ontology's instances when requested.

Although these responsibilities are attributed to the OM-i, this agent normally requests services from other specialized agents in order to perform these tasks (especially for the ontology matching process), e.g. see (Viamonte et al., 2011).

To improve performance, currently, the ontology matching process is performed externally to the negotiation process. It is considered a registry of ontologies that are recognized by the agent and a repository of possible alignments between them.

This information can be updated at any time, as new ontologies are discovered and ontology alignments are created.

We also consider that agents may represent their domain of knowledge using public ontologies, i.e. ontologies publicly accessible, having their own URL, either through a dedicated web page or being stored in web repositories. Therefore it is possible to gather ontologies used in an e-commerce context and discover possible alignments between them, or even collect already existent alignments from public web sources.

When the alignment negotiation is requested, the OM-i selects from its alignments repository the ones that involve both of the indicated ontologies. It then ranks, sorts and filters the alignments either by (i) requesting a SN-i to rank the alignments for the business negotiation, or (ii) by analyzing their coverage of the ontology's concepts and properties used by the B to describe the requested product. It then coordinates the alignment negotiation following the protocol previously described (cf. Section 3.3). In order to improve its recommendations, in each alignment negotiation's iteration, the OM-i stores and maintains information about the recommended alignments and the achieved agreements.

The transformation of a message's content (i.e. ontology's instance) is performed using the agreed alignment. This process is provided by information integration tools such as MAFRA Toolkit (Maedche et al., 2002) and it is transparent to the agents.

5 SOCIAL NETWORK BASED SUPPORT

The SN-based support is introduced in the system in order to enhance the communication's efficiency, by improving the evaluation of the alignments' adequacy to each business negotiation.

In previous work, we proposed two different models for this component: one based in explicit social networks (Viamonte et al., 2012) and another based in emergent social networks (Nascimento et al., 2012). In the first the business agents provide information about their own evaluations of their business partners and used ontology alignments, while in the latter the SN-i agents analyze the similarities between the agents' profiles and behavior, as well as the outcomes of their interactions. We consider this last model more interesting and adequate to our current problem since it is less demanding for the business agents (increasing the transparency of the process), and less dependent on them as well, allowing us to overcome problems such as the feedback credibility (Das et al., 2011). This model also allows us to take advantage of the collaboration between the system's agents.

During the market activity, the SN-i collects information about its participants and their interactions. Then it builds and maintains the relationship graph, applying SNA techniques (Wasserman and Faust, 1994) in order to capture proximity relations between agents, and adequacy relations from alignments to agents, which emerge during the agents' activities in the market. By combining this information, the SN-i is able to evaluate the adequacy of the alignments to each business negotiation.

A detailed description of the SN-i agent's model, as well as the fundaments behind it, can be found in (Nascimento et al., 2012). In this paper we present only the key aspects of its responsibilities, which are as follows.

Collect information throughout the market: the SN-i receives information from the other agents on the market which will allow it to, in return, support them in their tasks, e.g.: (i) business agents provide information about the profile of the entities they represent and about ontologies' usage and preferences; (ii) MF agents provide information about the business negotiations between the agents (e.g. both agents' identification, the used alignments, the negotiation outcome, the satisfaction of B with the deal); and (iii) OM-i agents provide information about ontologies, alignments and previous alignment negotiations.

Evaluate Agent-To-Agent proximity: based in some theories supported in the literature, the SN-i combines a series of factors in order to capture proximity relations between agents. These factors are: (i) the similarity between the agents' profiles and ontologies usage and preferences; (ii) the similarity between their interactions with other agents; (iii) the success rate of their own previous business negotiations; and (iv) the average satisfaction of B about purchased products from S.

Evaluate Alignment-To-Agent adequacy: to determine the adequacy of an alignment to an agent, the SN-i evaluates: (i) the alignment's coverage of the agent's used ontologies' concepts and properties (considering their respective relevance); (ii) the agent's success rate in business negotiations using the alignment; and (iii) the agent's average satisfaction in deals using the alignment.

Evaluate Alignment-To-Business-Negotiation adequacy: the adequacy of an alignment to a business negotiation will depend on many factors, namely: (i) the coverage of the alignment in relation to the requested product's description; (ii) the general success rate in negotiations using the alignment; (iii) the general average satisfaction in deals using the alignment; (iv) the adequacy of the alignment to each of the involved agents; and (v) the adequacy of the alignment to the agents closest (i.e. with high proximity relations) to the involved agents.

6 EXPERIMENTS AND RESULTS

In order to test and validate the AEMOS proposed model a new system was developed and several experiments were performed considering different e-commerce scenarios. In this section we present details about the implemented system and analyze the achieved results.

6.1 The AEMOS Prototype

The AEMOS system was developed in Open Agent Architecture (OAA). The OAA's Interagent Communication Language is the interface and communication language shared by all agents, and each agent is implemented in Java. The model can be distributed over a network of computers, which is a very important advantage considering the large amount of agents that may exist per market.

In order to test and validate the AEMOS model, and compare it with other AMEC approaches, we developed an application that enables the simulation of different e-commerce scenarios. The AEMOS simulator is very flexible as it allows defining the model to simulate, including the available services' configuration, the number of business agents, each agent's type, ontologies and strategies. The set-up of the AEMOS system is characterized by three dimensions: (i) the business agents' dimension, which includes the business entities' profiles, inventories/shopping lists and satisfaction measuring functions; (ii) the ontology services dimension, which includes the considered ontologies and alignments; and (iii) the SN dimension, which includes the SN-i agents' parameters to capture the emergent SN and perform evaluations. Each of these dimensions includes several parameters which can be configured.

6.2 Case Study

In this experiment we intend to demonstrate how the inclusion of ontology services, and combination with SN-based support, can improve the business negotiation's efficiency, leading to a higher satisfaction in the performed transactions.

Due to lack of space, the used configuration is not fully presented here. We describe only key aspects in order to provide a better understanding of the achieved results.

We study a simple market composed by 4 suppliers and 7 consumers, whose profiles are randomly generated. In order to correctly assess our proposal the agents negotiate the same type of product. To demonstrate the usefulness of our system we include situations where agents that use different ontologies could provide more satisfactory deals, i.e. supply products with more similar characteristics to the ones desired by the B, or that contemplate the ones that the B values most.

Note that in this experiment we are focusing on the ontology dimension of the negotiation, so other factors in the formulation/selection of a proposal (e.g. price, delivery time, quality of service) are considered to be similar and compatible for each agent. Therefore, the satisfaction of a B with a deal will correspond to the similarity between the purchased product and the desired one. The satisfaction value is obtained by averaging each attribute's similarity, weighing by the relevance that B attributes to each attribute. More details on this function can be found in (Nascimento et al., 2012).

We consider three different ontologies. For each pair of ontologies, two alignments were specified: (i) one containing all the correct correspondences between the ontologies; and (ii) another containing less of these correct correspondences and including some others which are incorrect.

6.3 Scenarios and Results

In order to test and validate our model, and based in the most frequent approaches for AMEC (cf. Section 2), we considered four different scenarios:

- Scenario 1 – A scenario without both ontology services and SN-based support. The agents negotiate only with agents that use the same ontology;
- Scenario 2 – A scenario with ontology services but no SN-based support. However, this scenario only considers the correct alignments. The OM-i agents evaluate the alignments' coverage of the concepts and properties used by the B to describe the requested product, and the agents choose the ones with higher coverage;

- Scenario 3 – A scenario similar to scenario 2 but considering all created alignments;
- Scenario 4 – A scenario with both ontology services and SN-based support. OM-i request an SN-i to evaluate the alignments and the agents choose the ones with higher score.

Each scenario ran several times in the AEMOS simulator. Table 1 presents the average satisfaction in deals obtained in each scenario, as well as the average adequacy of the used alignment.

Table 1: Average results from each scenario.

	Satisfaction in Deals	Alignments' Adequacy
Scenario 1	0.55	-
Scenario 2	0.65	-
Scenario 3	0.52	0.14
Scenario 4	0.62	0.30

Comparing the first two scenarios allows us to demonstrate how the system could benefit from the inclusion of the ontology services by itself. However, while in the first scenario the agents are limited to communicate with agents that use the same ontologies, the second represents an unrealistic situation, by considering that the ontology alignments are always semantically correct and equally adequate. When we include the incorrect alignments in the system the achieved satisfaction in deals is even lower than the one achieved in the first scenarios. This is due to the fact that, in this third scenario the agents will continue choosing the less adequate alignments which will cause a severe impact on their business satisfaction.

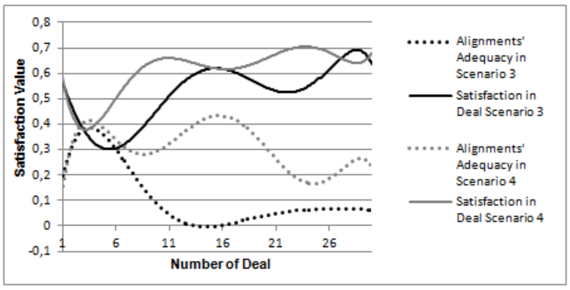

Figure 3: Trending of satisfaction in deals and adequacy of the used alignment in scenarios 3 and 4.

As Figure 3 illustrates, by including the SN-based component, the alignment recommendations tend to improve with time, allowing the agent to choose the most adequate alignments achieving a higher business satisfaction.

Moreover, by comparing the results achieved in scenarios 3 and 4, we can conclude that, when the SN-based support is included the agents need to negotiate less (20%) to achieved their business goals, there are less (29,4%) failed interactions, and there are more (14.3%) transacted products.

7 CONCLUSIONS AND FUTURE WORK

The exploitation of the ontology matching paradigm has been proposed in order to overcome the semantic heterogeneity problem which arises in open MAS. However, ontology matching may turn into a highly complex and time consuming process affecting the system's performance. Ontology matching is also a naturally ambiguous and subjective process, which may lead to different alignments that may be more or less adequate to each negotiation, affecting its efficiency and result. On the other hand, detecting incorrect or inadequate alignments is not a trivial task due to the different variables that may contribute for the negotiation outcome.

The system presented in this paper takes these issues into account, providing an AMEC system capable of enabling an efficient and transparent negotiation between agents, even when they use different ontologies. For that the system includes and combines ontology matching services and SN-based support. The ontology services allow agents to interact with a higher range of business partners, increasing the probability of achieving more satisfactory deals, while the SN-based component improves the business negotiations' efficiency by improving the recommendation/usage of ontology alignments.

The performed experiments have demonstrated the usefulness and effectiveness of the implemented model, being successful in the fulfilling of our initial goals. However, we believe there are some aspects in the systems which can be improved and future research directions can be referred. For example, the SN-based support component could be significantly improved, exploiting other SNA techniques, in other to achieve a more sophisticated model. Another aspect to improve soon is the negotiation protocol, both for business and ontology alignment negotiations. The currently implemented protocol is a legacy from the ISEM system and we believe that a more sophisticated/efficient protocol could be designed/adopted.

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