Enhancing Agent Mediated Electronic Markets with Ontology Matching Services and Social Network Support

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In agent mediated electronic commerce the diversity of the involved actors can lead to different conceptualizations of their needs and capabilities giving rise to semantic incompatibilities that might hamper negotiations and the fulfilling of satisfactory transactions. In order to provide help in the conversation among different agents, these systems should provide ontology services, more specifically, ontology matching services.

However, given the natural ambiguity of the ontology matching process, raising the possibility of multiple alignments between the same pair of ontologies, it is necessary to choose the one that best meets the interests of both agents. On the other hand, agents may possess different interests, therefore the ontology alignment may also become the object of further negotiation. In this context, the application and exploitation of relationships captured in social networks can result in the establishment of more accurate adequacy relations of ontology alignments to agents, as well as the improvement of the negotiations' efficiency and, consequently, the users' satisfaction with the electronic commerce system.

In this paper we present the AEMOS system which follows an ontology-based information integration approach, exploiting the ontology matching paradigm, improved by the application and exploitation of the relationships captured in the social networks.

Keywords: *Agent Mediated Electronic Markets, Ontology Alignment Negotiations, Emergent Social Networks.*

ACM Classifications: *I.2.11 Distributed Artificial Intelligence; I.2.4 Knowledge Representation Formalisms and Methods; I.2.6 Learning*

1. Introduction

In an efficient agent-mediated electronic commerce (AMEC), 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

Manuscript received: 31 October 2012
Communicating Editor: Rafael Valencia-Garcia

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), which imply that the negotiation processes and final agreements between consumers and suppliers 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). This is referred to as the ontology dimension of the business transactions.

On the other hand, in electronic commerce, the diversity of the involved actors can lead to different conceptualizations of their needs and capabilities, giving rise to semantic incompatibilities that might hamper the negotiation and prevent the fulfilling of satisfactory transactions. In order to provide help in the conversation among different agents, the electronic commerce systems must provide ontology services, more specifically, ontology matching services.

AEMOS (Agent-based Electronic Market with Ontology Services) (Silva *et al*, 2009; Viamonte *et al*, 2011; Viamonte *et al*, 2012; Nascimento *et al*, 2012) is an AMEC platform that provides ontology matching services, 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, AEMOS proposes an ontology-based information integration approach, exploiting the ontology matching paradigm (Euzenat and Shvaiko, 2007), selecting and suggesting possible alignments between the negotiation agents' ontologies and letting them choose which one should be used to translate the subsequent exchanged messages.

However, this approach raises new issues related to how the chosen ontology alignment may influence the business negotiation 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 affect 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 alignments is not an easy task. The negotiation may fail because the alignment is inadequate to the current context, or they can also fail simply because the supplier doesn't have the desired products, or even because the agents have different goals (e.g. conflicting prices).

Moreover, the agents representing consumers and suppliers have the final decision about which alignment should be used in the negotiation, so they can apply their own preferences. However, while the agents are well aware of their own ontologies, they are naturally not acquainted with the others agents' ontologies and with the ontology alignments in such ill-specified ever-evolving environments.

In order to overcome these issues, the relevance of social network analysis (SNA) in recommending ontology alignments for e-commerce negotiations is claimed, by including in the system a support component based in social networks (SN).

In this paper we present the AEMOS system, as a platform (for agent-based simulation of electronic commerce) that supports the conversation between heterogeneous agents through the recommendation of ontology alignments improved with SNA. We include an experiment (and a set of associate metrics) that shows how the exploitation of emergent SN for recommendation of ontology alignments could improve the performance of negotiation processes and the system in general.

We start by describing the research background (Section 2), and presenting a general overview of the AEMOS system (Section 3). The ontology services are then introduced (Section 4), and the SN-based support model is presented in scope of the AEMOS system (Section 5). In order to assess our proposal, a detailed experiment is described, which demonstrates how the SN-based support can improve the ontology alignment recommendations, and how this reflects in the business negotiations efficiency (Section 6). Finally we draw some closing remarks and suggest follow-up research efforts (Section 7).

2. Related Work

Research in agent mediated electronic markets (AMEC) has been pursued in different fields of knowledge, such as game theory, social sciences and artificial intelligence. Each field has concentrated on different aspects of the agent interactions, making the pertinent assumptions for the goal of their study. The literature in negotiation agents gives an important support to develop and implement AMEC systems (Lomuscio *et al*, 2001; Jennings *et al*, 2001; Sandholm and Vulkan, 1999; Krovi *et al*, 1999). However, usually each agent has its specific ontology to describe their universe of discourse, their needs and their capabilities, giving rise to a (semantic) heterogeneity problem that is seen as a cornerstone for agents' interoperability.

In general, current approaches for AMEC systems consider simplified and limited solutions to deal with semantic problems. Some consider the existence of an agreed ontology, which means that agents can only negotiate if they adopt the same ontology (Cui-Mei, 2009). Others develop and use their own ontology, such that to participate in the market each agent has to adopt this ontology (Viamonte *et al*, 2006; Qin *et al*, 2009). These approaches allow avoiding interoperability issues, although as stated by Saad *et al* (2008) these are simplistic and unrealistic alternatives that reduce the systems' flexibility. In our project, we are interested in enabling communication between agents even when they use different ontologies.

The Foundation for Intelligent Physical Agents (FIPA, 1996) has analyzed the interoperability problem in heterogeneous multi-agent systems (MAS) and has proposed an Ontology Agent (OA) for MAS platforms (FIPA, 2001). Among other responsibilities, the OA may provide the translation service of expressions between different ontologies or different content languages by itself, possibly as a wrapper to an ontology server. We propose an implementation of such a service, embedded in the electronic market.

We also support the idea that the proposed translation service may be achieved by exploiting the ontology matching paradigm (Euzenat and Shvaiko, 2007). Even though, some works suggest that the resulting alignment may not be satisfactory to both agents and can become the object of further negotiation between them (Mei *et al*, 2009).

Although, in general, all available approaches assume that actors are aware of and understand each other, there are already some approaches where the semantic problems are being considered; however each approach tends to focus on a particular aspect or phase of the known behaviour models. For example, Malucelli *et al* (2004) proposed ontology-based services to be integrated in the ForEV architecture in order to help in the virtual enterprise formation process (B2B). In our project, we are interested in studying MAS for business to consumer (B2C) domain, where other stages, as advocated by the Consumer Buying Behaviour model (CBB) (Runyon and Stewart, 1987) need to be contemplated in order to represent real situations.

On the other hand, we support the idea that SNA techniques (Wasserman and Faust, 1994) can be useful in order to capture proximity relations between agents as well as adequacy relations of ontology alignments to agents, which might be very important in order to provide support during both business and ontology alignments negotiations. SNA techniques have diverse applications in electronic commerce systems. For example, to detect malicious (or unreliable) users, which are frequent on the internet due to anonymity and the possibility of creating multiple accounts (Jyun-Cheng and Chui-Chen, 2008); to recommend products in which consumers might be interested, taking into account their preferences, previous purchases and recommendations made by customers with similar preferences or with a high level of influence on the social network (Zhou, 2009; Yu and Wang, 2010); to detect groups of customers or suppliers with similar interests in order to support the formation of buyer coalitions or virtual enterprises; and to perform market studies. This knowledge allows the improvement of the market's functioning by supporting agents on their decisions.

3. AEMOS System Overview

The AEMOS system is an innovative project (PTDC/EIA-EIA/104752/2008) supported by the Portuguese Agency for Scientific Research (FCT). It is based on the ISEM system (Viamonte *et al*, 2006), which is an agent-based simulation system for electronic commerce that aims to study agents' market strategies. In reality, the AEMOS system is an evolution of the ISEM system, keeping all its original functionalities, but allowing agents to use different ontologies to represent their domain of knowledge.

AEMOS provides ontology services in order to enable negotiation between agents that use different, but translatable or overlapping, ontologies. The system 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).

3.1 Multi-Agent Model

The multi-agent model includes several types of agents classified into two main categories namely, business (or external) agents and supporting (or internal) agents.

The business agents represent real world entities whose behaviour is intended to be simulated and studied. Currently, there are two types of agents in this category, namely:

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

The supporting agents are the ones who support the communication and negotiation between business agents. This category includes several agents responsible for the system's management, granting its dynamism, flexibility and correct functioning. A thorough description of these agents can be found in Viamonte *et al* (2011). In this paper we introduce only the most relevant actors in the interaction protocol, namely:

- Market Facilitator (MF) – an intermediary to the business negotiation process, agent that coordinates the interaction between business agents, being responsible for ensuring that the communicating agents are able to understand each other. Normally there are multiple agents of this type per marketplace. When a B agent is registered, a MF agent is associated such that, 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 approved alignment. Normally there are multiple agents of this type per marketplace. When a MF agent is initiated an OM-i agent is associated, such that, 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. Normally there are multiple agents of this type per marketplace. 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.

3.2 Interaction Protocol

To participate in the market, the business agents must first register, indicating the set of ontologies that they use and sharing (parts of) the profile of the entity they represent (cf. Figure 1). This information is handled by MF (cf. *Agents' Registration data* in Figure 2) and SN-i agents (cf. *Market Info Repository* in Figure 2 and Figure 4).

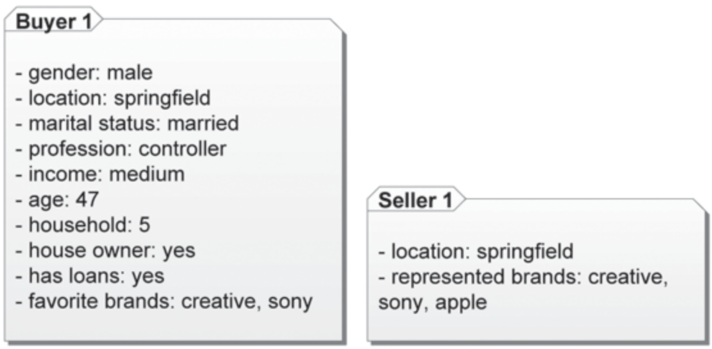


Figure 1: Examples of Buyer and Seller Agents' Profiles

Once registered, the agents are allowed to negotiate. For that the B agents start announcing their buying products and wait for S agents to formulate proposals.

When the negotiation starts, the MF must select the S agents that might be able to satisfy the B agent's request. Here, an ontology-based approach is followed, such that the MF selects both:

- the S agents that use the same ontology as the B agent; and,
- supported by the OM-i, the ones that use ontologies that can be aligned with it.

Therefore, the business negotiations may occur in two different scenarios:

- Both agents use the same ontology – the MF acts as a proxy between B and S, simply receiving and forwarding messages;
- 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 the 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 counter-proposals, terminating the negotiation when an agreement is achieved or when they have no more proposals to formulate.

Figure 2 illustrates the main interactions that may occur between the different agents during a business negotiation.

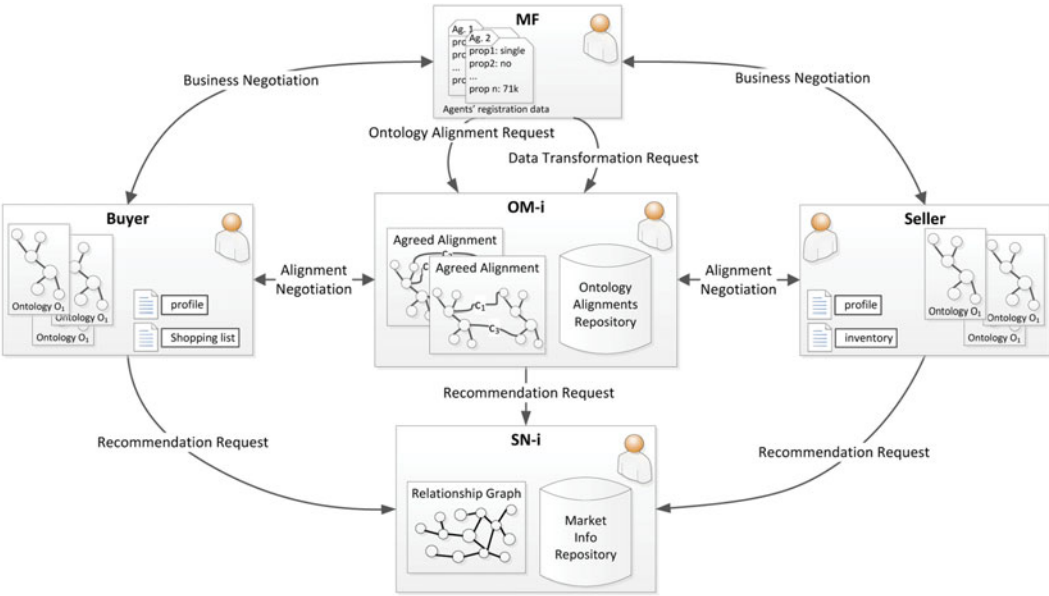


Figure 2: Interaction Protocol

As illustrated in Figure 2, during the market activity two types of negotiations may occur, namely (i) business negotiations, and (ii) ontology alignment negotiations.

In AEMOS the ISEM's business negotiation protocol, which is bilateral contracting, based on the FIPA's "Iterated Contract Net Interaction Protocol Specification" (FIPA, 2002), remains unaltered and therefore will not be addressed further.

Conversely, the ontology alignment negotiation is a new feature deserving our best attention.

3.3 Ontology Alignment Negotiation

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

In response to the MF's request, the OM-i selects the ontology alignments between S's and B's ontologies. Then it performs sorting and filtering actions following its internal criteria and/or requesting a SN-i to rank the alignments, constructing a set of possible alignments and their respective score, which will be sent to both B and S in an ontology alignment negotiation request. Each business agent, B and S, analyzes the recommended alignments taking into account their preferences and/or requesting advice from a SN-i, replying to the OM-i the list of alignments that 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 request made by the B. From that moment on, all the subsequent exchanged messages between the agents are forward to the OM-i for transformation.

4. The Ontology Services

When two agents that use different ontologies (to represent the same domain of knowledge) wish to exchange messages, a set of intermediary steps are necessary, namely:

- Discovering the correspondences between both ontologies – ontology matching process;
- Represent the discovered correspondences so they can be applied in data transformation – ontology alignment document;
- Transform the content of the message according to the ontology alignment – ontology's instances transformation process.

The ontology matching is a non trivial process which requires a deep knowledge about the conceptualizations behind both ontologies and their semantic similarities. Determining correspondences between ontologies' entities (i.e. ontologies' concepts or properties) is a naturally ambiguous and subjective process. The ontology matching process can be performed (i) manually, where a domain expert determines the correspondences between the ontologies; (ii) in a semi-automatic way, where the domain expert is supported by automatic ontology matching techniques; or (iii) in a completely automatic way, where the process is performed by using unsupervised automatic ontology matching techniques. The result from the ontology matching process consists of a document containing the semantic relations between the entities from the source ontology and the target ontology. This document is denominated ontology alignment.

Since the manual, or even semi-automatic, ontology matching may turn into a very complex and laborious process, aggravated with the size of the ontologies, the automatic approach may seem like the best solution. However, caution is needed when using this kind of technology which due to its low level of maturity and the complexity of the process, often results in inaccurate alignments.

In AEMOS the ontology services are provided by the Ontology Matching intermediary (OM-i) agent. The OM-i is responsible for the ontology alignments' management and for the ontology's instances transformation process, being able to propose ontology alignments, coordinate ontology alignment negotiations, and transform ontology's instances when requested. Its main components are illustrated in Figure 3.

Although being a responsibility attributed to the OM-i agents, the ontology matching process is delegated to specialized agents. A detailed description of a model for collaboration with such

Figure 3: OM-i Agent's Main Components

agents is presented in Viamonte *et al* (2011). However, in order to improve performance, conversely to the approach presented in the referred paper, the ontology matching process is now performed externally to the business negotiation process, in parallel to the market activities.

It is then considered a registry of the ontologies that are recognized and a repository of possible alignments between them (cf. *Ontology and Ontology Alignments*, in Figure 3, above). This information can be updated any time, as new ontologies are registered (e.g. during the business agents registration) and new ontology alignments are discovered.

It is also assumed that agents may represent their domain of knowledge using public ontologies, i.e., ontologies that are publicly accessible, having their own web page (e.g. the CEO – Consumer Electronics Ontology, 2011) or being stored in web repositories, such as TONES (2008), Falcons (2011) or Swoogle (2007). Therefore it is possible to gather ontologies that are used in an electronic commerce context and discover possible alignments between them, or even collect already existent alignments from public web sources (e.g. NCBO BioPortal, 2005). The ontology matching process can be performed multiple times, possibly using different methods, giving rise to various possibilities of alignment between the same pair of ontologies.

This approach allows us to separate such a complex and time-consuming process as the ontology matching from the business negotiation itself, as well as promoting the reuse of ontology alignments that may already exist. Moreover, note that in our current model, we are interested in allowing the usage of ontology alignments that might have been produced using different techniques (i.e. our approach is not restricted to the use of a determined matching technique).

The OM-i agents are able to provide information about ontologies and ontology alignments, e.g. when it is requested by the MF during the S agents' selection process (cf. Section 3.2), and have three main responsibilities:

- Recommend ontology alignments for a given business negotiation;
- Coordinating the ontology alignment negotiation process;
- Transforming data/message content, i.e. the ontology's instances.

When the ontology alignment negotiation is requested, the OM-i selects from its ontology alignments repository the ones that involve both ontologies. It then ranks the alignments using one of two methods (depending on the system's configuration):

- Analyze the alignment taking into account information about the request made by the B and previous agreements related to each of the involved agents;

- Request a SN-i to rank the alignments accordingly to both agents and the information about the request made by the B.

The first method is normally used when there is no SN-i in the system. The OM-i sorts the alignments taking into account the ontology's entities used by the B to describe the requested product, i.e., the alignments that cover a higher amount of ontology's entities used by the B will have a higher evaluation value.

In the second method the OM-i simply sorts the alignment by the score attributed by the SN-i possibly using a threshold for filtering.

The OM-i agent coordinates the ontology alignment negotiation following the protocol described in Section 3.3. In order to improve its recommendations in each negotiation iteration, the OM-i stores and maintains information about achieved ontology alignments' agreements (cf. *Agreements about Alignment*, in Figure 3) and recommended alignments during each ontology alignment negotiation (cf. *Suggested Alignments by Conversation*, in Figure 3).

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

5. The Social Network Support

In AEMOS the SN-based support is provided by Social Network intermediary (SN-i) agents, which are responsible for the discovery of agents' proximity relations and alignments' adequacy relations that emerge during the market activity.

The SN-i agents are introduced in the system in order to enhance the communication efficiency, supporting the OM-i agents at the ontology alignments recommendation and advising business agents about recommended alignments.

As can be seen from previous descriptions, these agents are able to perform these tasks without the SN-i agent's support. However there are some limitations that may affect the business negotiations efficiency.

Without using the SN-i agent's support, the OM-i agents assume that the alignments are always semantically correct and equally adequate to any situation involving a pair of ontologies, as long as some of the ontology's entities used on the requested product's description are contemplated in the alignment. However, since the use of different techniques may lead to different alignments, this accuracy is not guaranteed.

Moreover, the OM-i can select and rank ontology alignments taking into account the ontology's entities used to describe the B's requested product; however it has no information about the relevance that the B gives to each one (e.g. an alignment can contemplate more of the used entities but not the ones the B values most), and it doesn't consider the S's preferences either.

On the other hand, the B and S agents have the final decision about which alignments should be used in the business negotiation, so they can apply their preferences. However they may not possess knowledge that enables them to analyze and evaluate the alignments.

The SN-based component is introduced based on the assumption that taking into account captured emergent relationships between the agents and the overall usage of the ontology alignment, should result in a more accurate evaluation and usage of the ontology alignment, as well as a

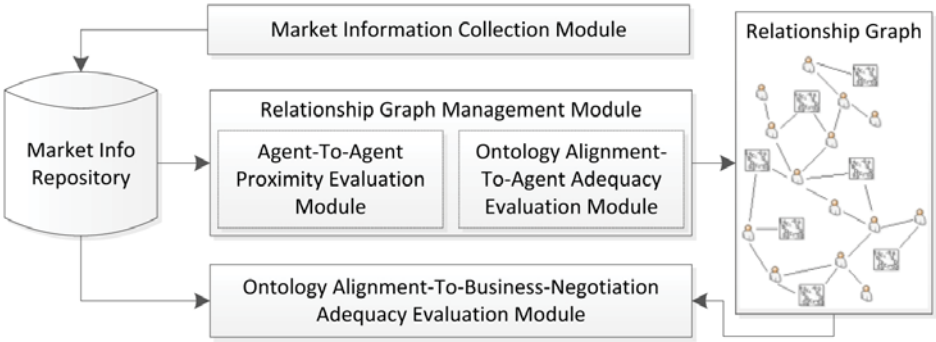


Figure 4: SN-i Agent's Main Components

higher negotiation efficiency between negotiation partners. Figure 4 illustrates the main components of a SN-i agent.

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, when requested, evaluate the adequacy of an alignment to a business negotiation. More specifically, the SN-i has four main responsibilities, namely:

- Collecting information about market participants and their activities;
- Capturing Agent-To-Agent proximity relations;
- Capturing Alignment-To-Agent adequacy relations;
- Determining the adequacy of an alignment to a business negotiation.

Each of these responsibilities will be addressed in the following subsections.

5.1 Collecting Information through the Market

The SN-i receives information from the other agents on the market that will allow it to, in return, support them in their tasks.

When a business agent registers in the market, it normally indicates the ontologies it uses and shares parts of the profile of the entity it represents. However, since this kind of agent normally has information about the products that it should buy/sell (cf. Figure 5 and Figure 6 in section 6.1.1), it can also provide information about the ontologies' entities used to describe the products, assigning to each one a value representing their relevance for the agent (obtained by the frequency they are used by the agent in the descriptions, and in the B agents' case also their use in restrictions to evaluate products' proposals, i.e. *Properties Relevance*, cf. Figure 5).

As an intermediary in transactions' negotiations, MF has the ability to provide impartial information about the business negotiations (e.g. identification of both agents, the used alignments, indication if the B tried to close deal, the negotiation outcome, the satisfaction of B with the deal).

OM-i can give information about known ontologies, existent ontology alignments and ontology alignment negotiations between the business agents.

```
Order
Ontology: MP3P
Product description:
...
  <mp3:AudioDevice rdf:ID="Audio1"
    mp3:hasManufacturer="Creative"
    <mp3:hasColor rdf:resource="#Black"/>
    <mp3:hasDepth rdf:resource="#D1"/>
    <mp3:hasHeight rdf:resource="#H1"/>
    <mp3:hasMonitor rdf:resource="#M1"/>
    <mp3:hasWeight rdf:resource="#We1"/>
    <mp3:hasWidth rdf:resource="#W1"/>
    <mp3:hasFunction rdf:resource="#Func1"/>
  </mp3:AudioDevice>
...
Properties Relevance:
  <mp3:hasManufacture>: 0,8
  <mp3:hasColor>: 0,9
  <mp3:hasHeight>: 0,2
  <mp3:hasWidth>: 0,2
  <mp3:hasWeight>: 0,3
...
```

```
Order
Ontology: SPDO
Product description:
...
  <spdo:Product rdf:ID="Audio1"
    spdo:description-of-product-
category="MP3Player">
    <spdo:hasColor rdf:resource="#Black"/>
    <spdo:hasDimension
rdf:resource="#Dim1"/>
    <spdo:hasManufacturer
rdf:resource="#Creative"/>
    <spdo:hasStatus rdf:resource="#New"/>
    <spdo:hasWeight rdf:resource="#We1"/>
  </spdo:Product>
...
Properties Relevance:
  <spdo:hasManufacture>: 0,8
  <spdo:hasColor>: 0,9
  <spdo:hasDimension>: 0,2
  <spdo:hasWeight>: 0,3
...
```

Figure 5: Products' Characteristics from Buyer Agents' Shopping Lists

5.2 Capturing Agent-To-Agent Proximity Relations

To capture proximity relationships between agents, a model is defined based on four theories supported in literature, namely:

- Two actors with similar profiles have similar interests and a higher degree of proximity (Luz, 2010);
- Two actors that have a similar relation with a determined element (in this case an agent or an ontology alignment) have a higher degree of proximity (Luz, 2010);
- The more two actors interact with each other, the more their level of proximity increases (in interactions with positive outcomes) or decreases (in interactions with negative outcomes) (Yu and Wang, 2010);
- The satisfaction of a consumer with the purchased product might give an indication of the supplier's service's quality (Jyun-Cheng and Chui-Chen, 2008).

Based on these four theories, four factors are considered in order to evaluate the proximity between two agents, namely:

- The similarity of the agents' profiles and valued ontologies' entities (*pSim*);
- The success rate of their own previous business negotiations (if it applies) (*srn*);
- The similarity of their interactions with other agents (*srnSim*);
- The satisfaction of the B about the purchased products from the S (if it applies) (*sat*).

For each pair of agents the SN-i performs a set of evaluations in order to determine the existence and intensity of a proximity relationship between them.

Definition 1: Let *a* and *b* be the agents under proximity evaluation, f_i be each evaluation factor and w_i be the weight assigned to each factor. We define the agent-to-agent proximity relation (*atar*) as a weighted average of the factors mentioned above, i.e.,

$$atar(a,b) = \sum (w_i . f_i(a,b)) / \sum w_i$$

The similarity of the agents' profiles and valued ontologies entities (*pSim*) is determined by comparing each common attribute from the agents' profiles, and by comparing the agents' valued entities from common ontologies, which are also treated as attributes. The methods to calculate the similarity between attributes will depend on their type (e.g. discrete/continuous, functional/non-functional). We apply the measures defined by Luz (2010) and Wu *et al* (2007), however, other measures may be used. The final value of this evaluation will be determined by averaging all obtained similarity values. The following definitions describe the main similarity measures used in the profiles' similarity evaluation.

Definition 2: Let *a* and *b* be as previously defined, *p* be the evaluated attribute, *p(a)* and *p(b)* be the values of the attribute *p* for agents *a* and *b* respectively, *max(p)* be the maximum limit of the value of the attribute *p* and *min(p)* its minimum limit. The continuous attribute similarity (*cas*) is given by Wu *et al* (2007):

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

Definition 3: Let *a, b* and *p* be as previously defined, *p(a)* and *p(b)* be the set of values of the attribute *p* for agents *a* and *b* respectively. The discrete functional attribute similarity (*dfas*) is given by Luz (2010):

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

Definition 4: Let *a, b, p, p(a)* and *p(b)* be as defined in the previous definition. The discrete non-functional attribute similarity (*dnfas*) is given by Luz (2010):

$$dnfas(a,b,p) = \frac{|p(a) \cap p(b)|}{|p(a) \cup p(b)|}$$

Definition 5: Let *a* and *b* be as previously defined, *tn(a,b)* be the total number of negotiations between them, *sn(a,b)* be the number of successful ones and *fn(a,b)* be the number of failed ones. The success rate of the negotiations (*srn*) between agents *a* and *b* is given by:

$$srn(a,b) = \begin{cases} \frac{sn(a,b) - fn(a,b)}{tn(a,b)} : tn(a,b) > 0 \\ 0 : otherwise \end{cases}$$

Definition 6: Let *a* and *b* be as previously defined, c_i be any agent with previous negotiations with both *a* and *b* and $srnS(a,b,c_i)$ be the evaluation of the similarity of *a* and *b* interactions with c_i. The similarity of the agents' interactions with other agents (*srnSim*) is given by:

$$srnSim(a,b) = Avg(srnS(a,b,c_i))$$

Definition 7: Let *a, b,* c_i, $srn(a,c_i)$ and $srn(b,c_i)$ be as previously defined. The absolute similarity value of *a* and *b* interactions with c_i ($abs(srnS(a,b,c_i))$) is given by:

$$abs(srnS(a,b,c_i)) = \left|1 - |srn(a,c_i) - srn(b,c_i)|\right|$$

being the final value positive if $srn(a,c_i)$ and $srn(b,c_i)$ are both positive or both negative, or negative otherwise.

Definition 8: Let *a* and *b* be as previously defined, now with *a* being a B agent and *b* an S agent. Let p_r be the desired product's description, p_p be the respective purchased/received product's description and $sat(a,b,p_p,p_r)$ be the satisfaction of agent *a* about p_p considering p_r. The satisfaction of *a* about the purchased products from *b* is given by:

$$sat(a,b) = Avg\left(sat(a,b,p_p,p_r)\right)$$

where $sat(a,b,p_p,p_r)$ is determined by the similarity between each products descriptions. For that similarity measures are used depending on each attribute's type. This measure is very agent dependent and therefore is left open. In the experiments section an example is presented (cf. Definition 18 in Section 6.1.1).

5.3 Capturing Alignment-To-Agent Adequacy Relations

The accuracy of the ontology alignment depends on many factors, including its semantics, granularity and coverage. Consequently, some agents achieve better business satisfaction using some alignments than using others. In our approach we assume that:

- if the alignments are correct, then the more ontology's entities it contemplates (of the ones used by the agent), the higher will be the efficiency of the interactions;
- some alignments may contain semantic errors, so it is necessary to evaluate the success rate of interactions involving them;
- a low satisfaction in closed deals may not be due to supplier's services' quality but in fact to the alignment's quality.

Based on these assumptions we consider three factors in order to determine the adequacy relation between an alignment and an agent:

- The alignment's coverage of the agent's valued ontologies' entities (*cov*);
- The agent's success rate in business negotiations using the alignment (*srna*);
- The agent's satisfaction in closed deals using the ontology alignment (*sata*).

Definition 9: Let *a* be the agent, *m* be the ontology alignment under adequacy evaluation, f_i be each evaluation factor and w_i be the weight assigned to each factor. We define the alignment-to-agent adequacy (*ataa*) as the weighted average of the factors mentioned above:

$$ataa(a,m) = \sum\left(w_i . f_i(a,m)\right) / \sum w_i$$

Definition 10: Let *a* and *m* be as previously defined, cp_i be an ontology's entity that is simultaneously valued by the agent and covered in the alignment, ncp_j be an ontology's entity that is valued by the agent but not covered in the alignment, and w_i and w_j be the weights assigned by *a* to the ontology's entities. The *m*'s coverage in relation to *a*'s valued ontologies' entities is given by:

$$cov(a,m) = \frac{\sum w_i . cp_i - \sum w_j . ncp_j}{\sum w_i + \sum w_j}$$

Definition 11: Let *a* and *m* be as previously defined, $tn(a,m)$ be the total number of *a*'s business negotiations using *m*, $sn(a,m)$ be the number of *a*'s successful business negotiations using *m* and $fn(a,m)$ be the number of *a*'s failed business negotiations using *m*. The *a*'s success rate when using *m* is given by:

$$srna(a,m) = \begin{cases} \dfrac{sn(a,m) - fn(a,m)}{tn(a,m)} : tn(a,m) > 0 \\ 0 : otherwise \end{cases}$$

Definition 12: Let *a* and *m* be as previously defined, now with *a* being a B agent. Let p_r and p_p be the desired and the purchased products' descriptions respectively and $sata(a,m,p_r,p_p)$ be the satisfaction of *a* in a deal using *m*. The satisfaction of *a* about the purchased products when using *m* is given by:

$$sata(a,m) = Avg\left(sata(a,m,p_r,p_p)\right)$$

where $sata(a,m,p_r,p_p)$ is determined in a similar way to $sat(a,b,p_p,p_r)$ defined above (cf. Definition 8 in Section 5.2).

5.4 Capturing Alignment-To-Business-Negotiation Adequacy

When requested by the OM-i, the SN-i attributes a confidence value to an ontology alignment recommendation that indicates its confidence that the alignment is adequate to the business negotiation. This approach combines:

- a content-based recommendation technique (useful when there is no information about the alignments' previous usage);
- concepts of trust-based recommendations (such as direct, indirect and global trust) (Das *et al*, 2011) using SNA.

In this evaluation we consider the following factors:

- The coverage of the alignment according to the requested product's description (*mce*);
- The alignment's success rate in business negotiations (*sra*);
- The satisfaction in closed deals involving the ontology alignment (*sa*);
- The adequacy of the alignment to B and S: *ataa(a,m)* and *ataa(b,m)*;
- The adequacy of the alignment to the agents closest to B and S: *rae(a,m)* and *rae(b,m)*;

Definition 13: Let *a* be one of the agents in the business negotiation, *b* be the other agent, *m* be the alignment under adequacy evaluation, *pr* be the description of the requested product's description (cf. *Product description* in Figure 5), f_i be each evaluation factor and w_i be the weight assigned to each factor. The alignment-to-business-negotiation adequacy (*atbc*) is given by the weighted average of several factors:

$$atbc(a,b,m,p_r) = \sum(w_i . f_i)/\sum w_i$$

Definition 14: Let *m* be as previously defined, p_r be the requested product's description, $pc(p_r)$ be the set of ontology's entities used to describe the product and $pc(m)$ be the set of ontology's entities covered in the alignment. The *m*'s coverage in relation to p_r (*mce*) is given by:

$$mce(p_r,m) = \frac{|pc(p_r) \cap pc(m)|}{|pc(p_r) \cup pc(m)|}$$

Definition 15: The alignment success rate (*sra*) is given by *srna* (cf. Definition 11 in Section 5.3) for any agent, i.e. *srna(_,m)*.

Definition 16: Let *m* be as previously defined. The general satisfaction using the alignment *m* is given by:

$$sa(m) = Avg\left(sata(\_,m,\_,\_)\right)$$

where *sata(_,m,_,_)* is the satisfaction of any agent using *m* for any purchased product (cf. Definition 12 in Section 5.3).

Definition 17: Let a and m be as previously defined, c_i be each of the agents closest to a, i.e. those that have a high proximity relation with a, and $atar(a,c_i)$ and $ataa(c_i,m)$ be as defined in Definitions 1 and 6 respectively. The adequacy of m to the agents closest to a is given by:

$$rae(a,m) = \frac{\sum atar(a,c_i) * ataa(c_i,m)}{\sum atar(a,c_i)}$$

where c_i can be directly related to a or indirectly (i.e. when there is a multi-steps path from a to c_i). In the latter case the value of the relation from a to c_i is obtained by the accumulated product of each relation value in the path.

6. Implementation and Experiments

In order to validate the proposed model, the AEMOS system was developed based in the Open Agent Architecture (OAA, s.d.), being the OAA's Interagent Communication Language, the interface and communication language shared by all agents. Each agent is implemented in Java (1995), and the model can be distributed over a network of computers, which is a very important advantage to increase simulation runs for scenarios with a large amount of agents.

AEMOS system is very flexible as it is possible to define the model to simulate, including the number of agents, each agent's type, ontologies and strategies. By using the AEMOS's GUI, it is possible to configure and visualize the parameters of the scenario to simulate, as well as observing the simulation evolution. More information about this GUI can be found in Viamonte *et al* (2011).

In order to evaluate the model described in the previous section, several experiments were performed. The goal is to show the relevance of the SN-i agent's confidence value upon the recommended ontology alignments, and their relevance in the business negotiation.

6.1 Set-up

The simulation set-up is characterized by three dimensions: (i) the business agents dimension which includes their profiles, inventories/shopping lists and satisfaction measuring functions, (ii) the ontology alignments, and (iii) the SN-i agent's parameters.

Each of these dimensions is presented in the following subsections.

6.1.1 Consumers and Suppliers

A simple marketplace is considered, composed of four suppliers and seven consumers, whose profiles are represented in Table 1 and Table 2 respectively.

	S1	**S2**	**S3**	**S4**
Location	Lisbon Madrid Paris	Lisbon Paris	Lisbon London	London Paris Madrid
Represented Brands	Creative Apple	Creative Sony	Creative Samsung	Creative Apple

Table 1: Case Study: Seller Agents' Profiles

In order to correctly assess our proposal, the agents will negotiate the same product: an audio device, with similar characteristics. Notice that different ontologies are used in the shopping lists and inventories (cf. Figure 5 and Figure 6).

	B1	B2	B3	B4	B5	B6	B7
Gender	Female	Male	Female	Female	Male	Male	Male
Marital Status	Single	Single	Single	Married	Married	Single	Single
Location	Lisbon	Lisbon	London	Madrid	Madrid	London	Lisbon
Profession	Student	Professor	Student	Housewife	Controller	M.D.	M.D.
Income	Low	High	Low	Low	High	High	High
Age	19	30	18	42	42	55	45
Household	0	2	0	5	5	0	0
Owns House	No	Yes	No	Yes	Yes	Yes	Yes
Has Loans	No	Yes	No	Yes	Yes	Yes	Yes
Favourite Brands	Creative Sony Samsung	Creative Apple Sony	Creative Apple Sony	Creative Apple	Creative Apple	Apple	Apple Sony

Table 2: Case Study: Buyer Agents' Profiles

```
Offer
Ontology: CEO
Product description:
...
  <ceo:MP3Player rdf:ID="Creative-Zen-X-Fi1"
    gr:color="Black"
    ceo:hasDisplay="true">
    <gr:hasManufacturer rdf:resource="#Creative"/>
    <ceo:hasDepth rdf:resource="#D1"/>
    <ceo:hasHeight rdf:resource="#H1"/>
    <ceo:hasWidth rdf:resource="#W1"/>
    <ceo:hasWeight rdf:resource="#We1"/>
    <ceo:hasFeatures rdf:resource="#Func1"/>
  </cei:MP3Player>
  ....
```

Figure 6: Product Characteristics from Seller Agents' Inventories

Notice that in the current experiments we are focusing on the ontology dimension of the negotiation, so other relevant 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.

Both S agents and B agents need to be able to compare product descriptions (i.e., ontology's instances), in order to decide if they match and formulate/accept product proposals. This is achieved by using a shared similarity measuring function, which is represented as follows:

Definition 18: Let a be the B agent, b be the S agent, p_r be the requested product's description, p_p be the proposed product's description, p_{p_i} and p_{r_i} be the ontology's entity to compare in each description, *sim* be the used similarity function, and w_i be the value that a attributes to the analyzed ontology's entity. The similarity between two product descriptions (*prodSim*) is obtained by averaging the similarities between the ontology's entities of both descriptions, i.e.,

$$prodSim(a, b, p_p, p_r) = \mathrm{w_i}.\left(sim\left(p_{p_i}, p_{r_i}\right)\right)$$

here *sim* is any similarity function varying according to the property's type (e.g. normally the levenshtein distance is used for string values). This function is used by both B and S agents. Thus, it is important to note that p_r is the requested/desired product by B, and p_p is either a product from S's inventory (when S is searching for proposals) or a proposed product by S (when B is analyzing the proposal). This function also determines the satisfaction of a B with the deal. In this case p_p represents the purchased product.

Despite using the same similarity measuring function each agent can attribute a different relevance (w_i) to each property (c.f. *Properties Relevance* in Figure 5, Section 5.1).

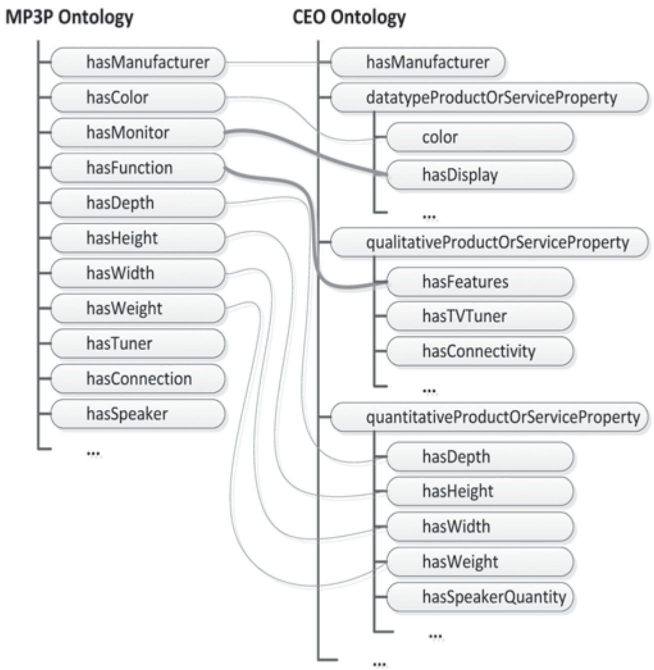
6.1.2 Ontologies and Ontology Alignments

As illustrated in Figures 5 and 6, three different ontologies are considered to describe audio devices:

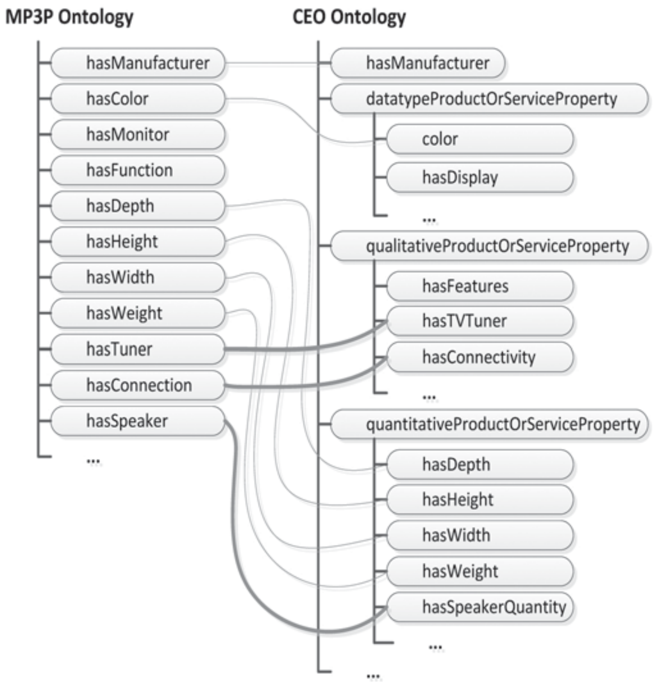
- CEO (2011): Consumer Electronics Ontology, an ontology to describe electronic devices such as MP3 Players, TVs, Printers, among others; used by all S agents;
- MP3P (2011): MP3 Player, an ontology to describe audio devices; used by agents B1, B2, B3 and B4;
- SPDO (2010): Smart Product Description Ontology, a generic ontology to describe products; used by agents B5, B6 and B7.

This scenario ensures that the B and S agents always use different ontologies and, therefore, the satisfaction in deals will depend on the selected alignment.

For each pair of ontologies, two alignments were developed: one semantically valid and another semantically incorrect. The alignments were developed manually, ensuring that one of the alignments (the semantically correct) aligns all the concepts and properties which are correspondent between the ontologies, while the other (the semantically incorrect) considers less of these correct correspondences and includes some others which are incorrect. Figure 7 presents an illustration of



(a) Semantically Valid and Complete Alignment



(b) Semantically Incorrect Alignment

Figure 7: Examples of the Used Correct and Incorrect Alignments between Ontologies MP3P and CEO

a semantically correct and a semantically incorrect alignment from MP3P ontology to CEO ontology. In this illustration, we highlighted the correspondences that are included in one of the alignments and not in the other. The first alignment (a) represents the result of a matching process performed by a domain expert, while the second (b) was developed based on the results of an automatic matching process (i.e. using Falcon-OA matcher (Hu and Qu, 2008) in the GOALS system (Maio and Silva, 2009)).

By analyzing both ontologies, it is possible to conclude that the three different correspondences included in the second alignment are not correct. Therefore, although the first alignment includes a lower amount of correspondences between the ontologies (having a lower coverage), it includes a higher amount of correct correspondences than the second alignment.

The alignments are identified by the names of the involved ontologies in the format “<Source Ontology>To<Target Ontology>”, for example, an alignment from the ontology CEO to the ontology MP3P will be denominated “CEOToMP3P”. For the semantically incorrect alignments the suffix “_Bad” is added, for example, the incorrect version of the mentioned alignment would be identified as “CEOToMP3P_Bad”. These identifications are used in a later section of this chapter (cf. Table 6 and Table 7 in Section 6.2).

6.1.3 SN-i Agent’s Parameters

In this case study the SN-i agent weights its evaluation factors using the weight specified on its configuration. Since, in the current model, agents from the same type don’t interact with each other, the relations between them should be based only on their profiles and actions similarity. The weights used by the SN-i agent in each of its evaluations are presented in the following tables.

	pSim	*srnSim*	*srn*	*sat*
Weight for agents of different categories	0.30	0.20	0.25	0.25
Weight for agents of the same category	0.55	0.45	–	–

Table 3: Case Study: Agent-To-Agent Proximity Relationship Evaluation Factors Weights

	cov	*srna*	*sata*
Weight	0.30	0.40	0.30

Table 4: Case Study: Alignment-To-Agent Adequacy Evaluation Factors Weights

	mce	*sra*	*sa*	*ataa(a,m)*	*ataa(b,m)*	*rae(a,m)*	*rae(b,m)*
Weight	0.10	0.20	0.20	0.15	0.15	0.10	0.10

Table 5: Case Study: Alignment-To-Negotiation Adequacy Evaluation Factors Weights

6.2 Scenarios and Results

Based on the previous set-up, two scenarios are proposed respecting the marketplace functionalities:

- Where the SN-i agent's advice is followed: the OM-i agent consults the SN-i agent in order to decide which alignments to recommend;
- Where the SN-i agent's advice is ignored: the OM-i agent analyses the ontology alignments taking into account the description of the requested product.

In both scenarios the business agents select the alignments proposed by the OM-i with highest scores.

In the first scenario the SN-i agent starts building the initial relationship graph. Figure 8 (on the following page) illustrates the initial agents' relationship graph, i.e. the initially captured proximity relations between agents.

The initial adequacy relations between ontology alignments and agents (ataa) are presented in Table 6.

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**S1**	**S2**	**S3**	**S4**
CEOToMP3P	0.21	**0.21**	0.21	0.21	-	-	-	**0.03**	**0.03**	0.03	0.03
MP3PToCEO	0.19	**0.19**	0.19	0.19	-	-	-	**0.07**	**0.07**	0.07	0.07
CEOToMP3P_Bad	0.25	**0.25**	0.25	0.25	-	-	-	**0.17**	**0.17**	0.17	0.17
MP3PToCEO_Bad	0.24	**0.24**	0.24	0.24	-	-	-	**0.10**	**0.10**	0.10	0.10
MP3PToSPDO	0.16	**0.16**	0.16	0.16	0.28	0.28	0.28	-	-	-	-
SPDOToMP3P	0.13	**0.13**	0.13	0.13	0.27	0.27	0.27	-	-	-	-
MP3PToSPDO_Bad	0.06	**0.06**	0.06	0.06	0.13	0.13	0.13	-	-	-	-
SPDOToMP3P_Bad	-	-	-	-	0.28	0.28	0.28	-	-	-	-
CEOToSPDO	-	-	-	-	0.30	0.30	0.30	-0.07	-0.07	-0.07	-0.07
SPDOToCEO	-	-	-	-	0.28	0.28	0.28	-0.07	-0.07	-0.07	-0.07
CEOToSPDO_Bad	-	-	-	-	0.28	0.28	0.28	-0.07	-0.07	-0.07	-0.07
SPDOToCEO_Bad	-	-	-	-	0.28	0.28	0.28	-0.03	-0.03	-0.03	-0.03

Table 6: Case Study: Initial Alignment-To-Agent Adequacy Relations

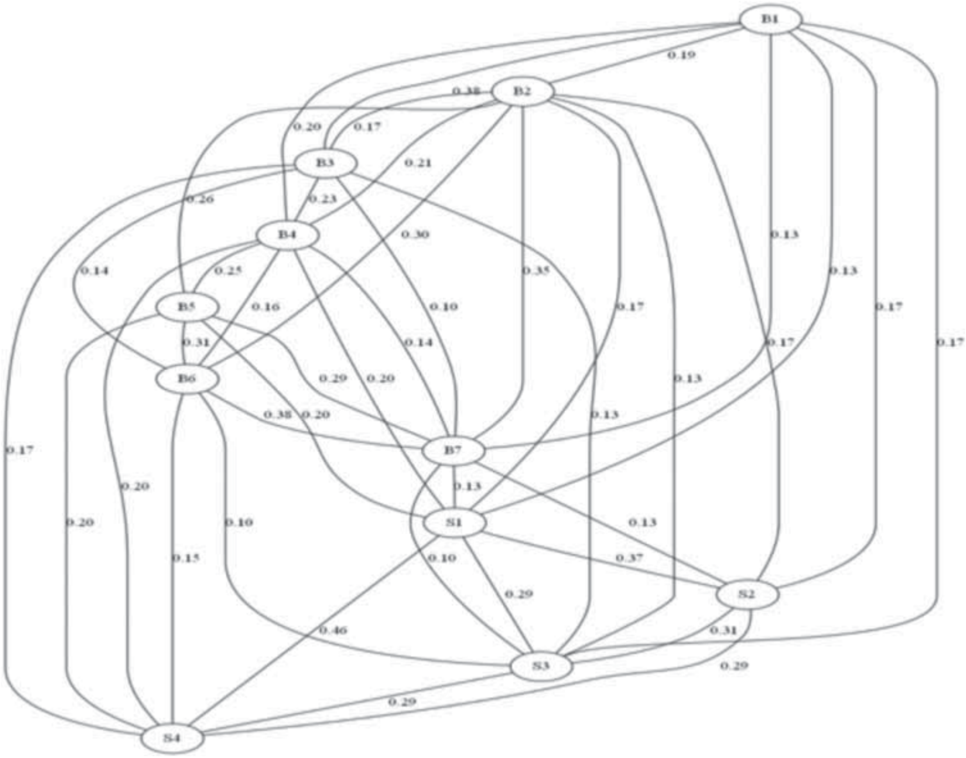


Figure 8: Case Study: Initial Agent-To-Agent Proximity Relations

In this scenario the agents using the same ontology describe the product in a similar way and have the same relevant attributes. Therefore, as demonstrated in Table 6, their initial relations with alignments will be identical (e.g. cf. agents S1 and S2 in Table 6).

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**S1**	**S2**	**S3**	**S4**
CEOToMP3P	0.01	**0.05**	0.10	0.40	–	–	–	0.15	0.48	0.16	0.47
MP3PToCEO	0.02	**0.08**	0.22	0.17	–	–	–	0.21	0.42	0.10	0.41
CEOToMP3P_Bad	-0.03	**-0.06**	-0.14	-0.10	–	–	–	-0.06	-0.06	-0.06	-0.03
MP3PToCEO_Bad	-0.02	**0.02**	-0.06	-0.20	–	–	–	-0.19	-0.19	-0.19	-0.17
MP3PToSPDO	0.37	**0.36**	0.37	0.27	0.66	0.67	0.66	–	–	–	–
SPDOToMP3P	0.30	**0.27**	0.35	0.10	0.62	0.62	0.62	–	–	–	–
MP3PToSPDO_Bad	0.15	**0.10**	0.16	0.15	0.66	0.66	0.63	–	–	–	–
SPDOToMP3P_Bad	–	–	–	–	0.29	0.29	0.27	–	–	–	–
CEOToSPDO	–	–	–	–	0.08	0.09	0.10	0.23	0.31	0.40	0.59
SPDOToCEO	–	–	–	–	0.06	0.11	0.12	0.23	0.31	0.40	0.57
CEOToSPDO_Bad	–	–	–	–	-0.03	-0.02	-0.03	-0.53	-0.53	-0.53	-0.51
SPDOToCEO_Bad	–	–	–	–	-0.02	-0.03	-0.04	-0.53	-0.53	-0.53	-0.51

Table 7: Case Study: Updated Alignment-To-Agent Adequacy Relations

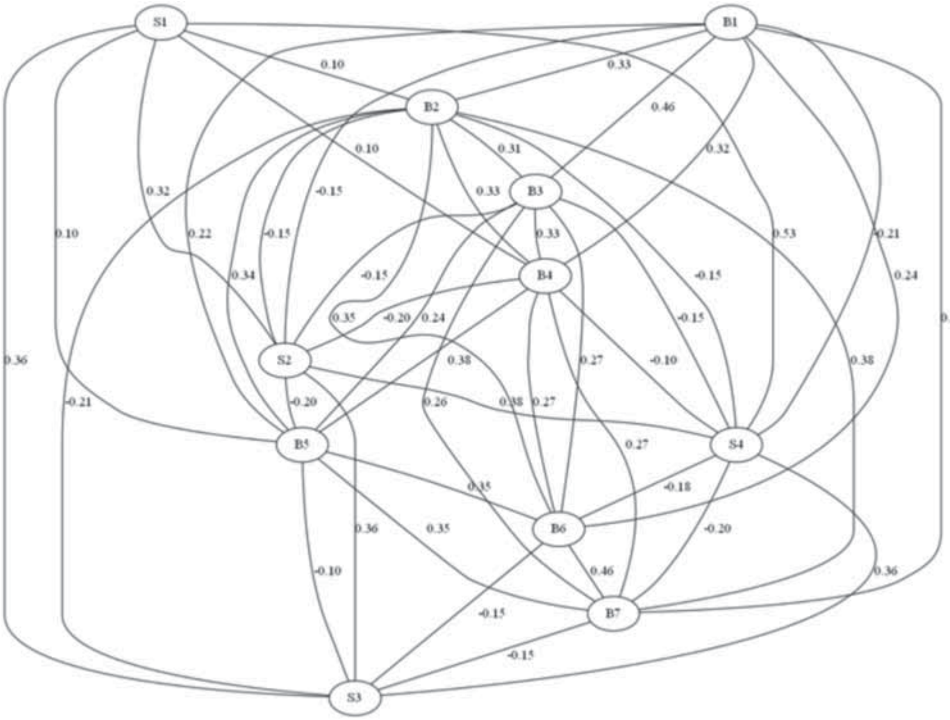


Figure 9: Case Study: Updated Agent-To-Agent Proximity Relations

During the market activity the SN-i agent updates this graph according to the information it receives. Figure 9 illustrates the agents' relationships graph in a further point of the simulation.

The updated ontology alignment adequacy relations (*ataa*) are presented in Table 7. As demonstrated, when the SN-i agent is used the ontology alignments' adequacy to the agents evolves during the simulation as they are used in more business negotiations (e.g., cf. B2 in Table 6 and Table 7).

The presented scenarios ran several times in the AEMOS system. A sample of the average results between the two scenarios is captured in Figure 10.

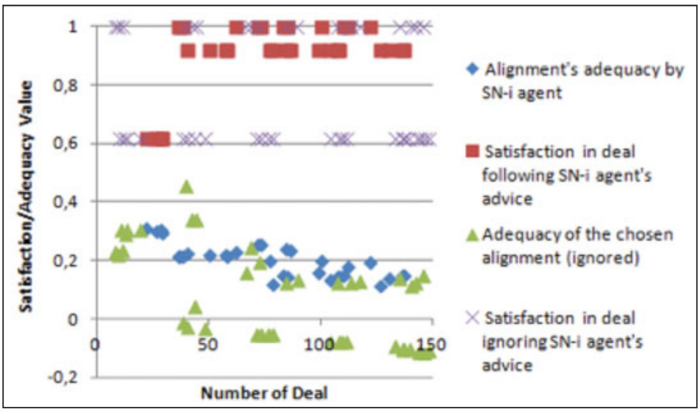


Figure 10: Average Results With and Without the SN-i

Figure 10 allows comparing the relation between the adequacy of the used ontology alignment and the B agent's satisfaction in the achieved deal, in each of the two scenarios. As illustrated in this figure, when the SN-i agent's advice is followed, normally, the adequacy of the chosen alignment is higher and so is the satisfaction of the B agent with the deals.

The average results of the simulations are presented in the following table.

	Following SN-i agent	Ignoring SN-i agent
Average Satisfaction with Deals	0.917	0.781
Total Number of Negotiations	138.5	154
Number of Failed Negotiations	115.5	139
Number of Transacted Products	120	53.75

Table 8: Case Study: Average Results of the Simulations

As can be observed in the previous results, when the SN-i agent's advice is ignored, the agents will continue choosing the inadequate alignments which will cause a severe impact on their business negotiations. Since there are more failed negotiations, the agents will have to spend more time negotiating until they are able to satisfy their business goals, increasing the probability of reaching their deadlines and not be able to transact all the products.

The experiments indicate that when the SN component is included in the system, the achieved results are highly improved:

1. There is a higher satisfaction in closed deals;
2. The agents need to negotiate less to satisfy their business goals;
3. There are less failed negotiations; and,
4. There are more transacted products.

These results validate the models presented in the previous sections, suggesting that a SN component can greatly improve the business negotiations efficiency by improving the recommendation of ontology alignments.

7. Conclusions and Future Work

In this paper is presented an agent-based e-commerce platform that provides ontology services, including the recommendation of possible ontology alignments between the negotiation agents' ontologies.

Due to its natural ambiguity and subjectivity, the ontologies matching process can lead to different alignments that may affect the negotiation efficiency. The accuracy and adequacy of an ontology alignment is very important in e-commerce business negotiations. However, detecting semantically accurate and adequate alignments is not an easy task due to the different variables that may determine the success of the negotiation.

The presented model is based on the assumption that by considering the usage of the alignment in previous negotiations, and by analyzing the overall interactions between agents, it is possible to capture the adequacy of the alignment to a negotiation.

The SN is emergent and virtual, as opposed to an explicitly defined SN. The initial agents' proximity relations are based on their profile similarity and based on their ontologies' entities preferences, therefore this SN is relatively simple to capture and maintain. Nevertheless, as shown in the experimentation results, it is very effective, as it allows the SN-i agent to progressively recommend the most adequate ontology alignments to the agents in a specific negotiation.

The SN-i agent's model is based on several established theories that drive our implementation decisions. Despite the described experiments demonstrating the usefulness of the model, further experiments should be carried out in order to thoroughly assess the proposal and fully generalize its application.

Acknowledgements

This work is supported by FEDER Funds through the "Programa Operacional Factores de Competitividade - COMPETE" program and by National Funds through FCT "Fundação para a Ciência e Tecnologia" under the projects: FCOMP-01-0124-FEDER-PEst-OE/EEI/UI0760/2011; PTDC/EIA-EIA/104752/2008.

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