B2B TRANSACTIONS ENHANCED WITH ONTOLOGY-BASED SERVICES

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Abstract: In an efficient Virtual Enterprise (VE), where all the partners, both sending and receiving messages have to lead to acceptable and meaningful agreements, it is necessary to have common standards (an interaction protocol to achieve deals, a language for describing the messages' content and ontology for describing the domain's knowledge). This paper introduces first the ForEV platform, implemented through a Multi-Agent System. This platform facilitates partners' selection automatic process in the context of VE and includes a negotiation protocol through multi-criteria and distributed constraint formalisms, as well as a reinforcement learning algorithm. Then, Ontology-based Services are proposed to be integrated in ForEV architecture in order to help in the VE formation process. These services will make the platform more open, enabling the establishment of the negotiation process between agents with different ontologies although representing the same domain of knowledge. An Ontology-based Services Agent is the responsible for providing the Ontology-based Services and monitoring the whole agents interaction just in time, without needing of a previous and tedious complete ontology mapping process. In our architecture each agent (either market or enterprise) has its own architecture and functionalities (some developer will design and build the ontology with some tool and, later, the agent will access the generated file/database), which implies the heterogeneity of the all Multi-Agent System.

1 INTRODUCTION

ForEV is an agent-based platform we have developed aiming to facilitate the partners' selection automatic process in the context of Virtual Enterprise (VE). ForEV provides tools for agents, as enterprises' delegates, to engage themselves in complex negotiations including multi-attribute evaluation and qualitative appreciation of proposals. Both the former and latter features are important in a B2B negotiation.

In business transactions, due to the nature of the goods/services traded, these goods/services are described through multiple attributes (e.g. price and quality), which imply that negotiation process and final agreements between seller and supplier must be enhanced with the capability to both understand the terms and conditions of the transaction (e.g. vocabularies semantics, currencies to denote different prices, different units to represent measures or mutual dependencies of products).

A critical factor for the efficiency of the future negotiation processes and the success of the potential settlements is an agreement among the negotiating parties about how the issues of a negotiation are represented in the negotiation and what this representation means to each of the negotiating parties. This problem is referred to as the ontology problem of electronic negotiations (Ströbel, 2001). Distributors, manufactures, and services providers may have a radically different ontology that differs significantly in format, structure, and meaning.

Given the increasingly complex requirements of applications, the need for rich, consistent and reusable semantics, the growth of semantically interoperable enterprises into knowledge-based communities, and the evolution and adoption of semantic web technologies, ontologies represent the best answer to the demand for intelligent systems that operate closer to the human conceptual level (Obrst et al., 2003).

A specific Ontology-based Services Agent is proposed to help in the VE formation process, providing useful advices on how to better negotiate specific items and how different terms may be understood as equivalent. It is up to this Ontology-based Services Agent to make it possible negotiations in the Multi-Agent System and finally lead to acceptable and meaningful agreements.

The remainder of this paper discusses first the ForEV platform, including the architecture as well as explains the Q-Negotiation algorithm and the distributed constraint satisfaction of parallel negotiations. Some ontology approaches are presented in Section 3. This Section discusses also about Ontologies and Business Transactions and about the interoperability problems. The Ontology-based Services proposed as well as the needs change in ForEV to integrate the Ontology-based Services Agent, are presented in Section 4. The technologies used for implementation are discussed in Section 5 and the conclusions are discussed in the last Section.

2 FOREV PLATFORM

ForEV is an appropriate computing platform, which includes and combines negotiation's methods in the context of Multi-Agent Systems, which is suitable for Virtual Enterprise formation scenario.

The negotiation's methods try to satisfy the electronic market dynamics and competitiveness requirements. Maintaining enterprise utility related information private is here enforced without endangering its own negotiation power in that market. An entity participating in a business transaction, and an enterprise in particular, tries to hide from the market its own private evaluation of the goods under negotiation.

On the other hand, adaptation should also be another important characteristic to be included in any entity present in an electronic market. In fact, although an enterprise doing business does not know, in advance, its own potential partners, it has, nevertheless, to pay attention to the eventual market changes and to adapt as soon as possible to those changes.

Therefore, the privacy and learning characteristics have been included in the heart of the proposed negotiation process – the "Q-Negotiation" algorithm. "Q-Negotiation" is an iterative, adaptive, multi-attribute negotiation algorithm using qualitative argumentation.

Moreover, in order to solve the simultaneous partial inter-dependent negotiations dependency problem, arising during the Virtual Enterprise formation phase, a specific algorithm has been developed. This algorithm is a decentralized distributed dependency satisfaction problem solver, which is based on the progressive utility decrement concept. Through the application of this algorithm, the Multi-Agent System is able to, in a non-centralised way, select that solution which minimizes the total agents' utility decrement value for those agents involved in that specific dependency.

2.1 ForEV Architecture

ForEV was developed to model the interactions between different entities, named enterprises and customers, in order to select among a set of individual enterprises, the subset that may satisfy a specific customer need. The set of selected enterprises will form a temporary consortium named Virtual Enterprise, which will exist during the time needed to satisfy the customer requirements.

The use of a Multi-Agent System methodology seems to be an adequate paradigm for the system architecture, since enterprises are independent and have individual objectives and behaviours.

Agents represent the enterprises (Enterprise Agent) and customers (Market Agent) in the system. The Enterprise Agents (EA) and Market Agent (MA) meet each other in a marketplace where they cooperate with the objective of providing or buying some good (product/service), keeping their own preferences and goals. The goods under transaction are described by an ontology (Ont) that should be known and understood by all the participants. The system contains another agent, the Register Agent (RA), which is responsible for creating and maintaining the domain ontology.

The Multi-Agent System is then represented by the n-tuple: ForEV=<RA, {MA}, {EA}, Ont>. A brief description of the agents presented in the system is given in next paragraphs.

Register Agent (RA) is responsible for the local market creation and maintenance. The Enterprise and Market Agents announce their competencies and needs, respectively, in the market. The Register

Agent establishes the contact between the Market and the Enterprise Agents that may have related interests. Actually, the RA is also responsible for creating and presenting the domain ontology to all participants.

Figure 1 presents the RA role while establishing contact between relevant Enterprise and Market Agents. The RA receives a message from MA_k informing that it needs the good "X" (message 1). The RA also receives a message from EA_i informing the possibility of providing components "X_a" and "Y_b" (message 2), where X_a is one of the X's components, and Y_b is one of the Y's components. The RA presents MA_k to EA_i, because MA_k is interested in a competency that EA_i may offer (message 3). The EA_i sends then a message directly to MA_k offering "X_a" (message 4).

Another task assigned to RA is to maintain and manage the domain ontology. For the moment, this task only includes the syntactic representation of the domain concepts, which are the customer' needs (product or service) and the enterprises' competencies (components). The RA responsibility in this field should be enhanced with Ontology-based Services, which allow that different agents may use their private ontology instead of being obliged to use the RA pre-defined ontology. A solution to this issue is proposed in Section 4.

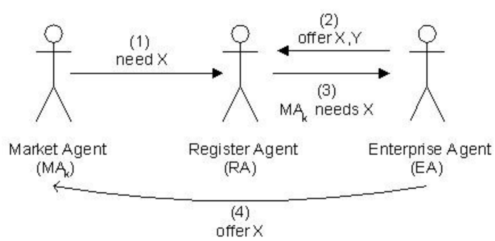

Figure 1 - RA establishing contact

Market Agent (MA) represents the customer. This agent announces in the market the need for a specific good. The MA_k is responsible for selecting among a set of EA_is, the subset that will form the Virtual Enterprise. The MA need (good) is described by a list of components (Cmpt), and each component is described by a list of attributes (Atb). The MA's preferences are codified in the relative order by which attribute are defined in the component structure definition: $Cmpt_x=\{Atb_{x1}, Atb_{x2}, Atb_{x3}\}$ with $Atb_{x1} >_{imp} Atb_{x2} >_{imp} Atb_{x3}$, where $>_{imp}$ means "more important than". In this case it means that Atb_{x1} is more important than Atb_{x2}, and Atb_{x2} is more important than Atb_{x3}. This order is relevant for the negotiation process. The attributes' values are also represented in a preference order. $Val\_Atb=\{Value_1, Value_2, \ldots Value_n\}$ with $Value_1 >_{imp} Value_2 >_{imp} \ldots >_{imp} Value_n$.

The selection of the individual enterprises (EAs), which will compose the VE, starts with the messages sent by EAs to MA_k offering components (i.e., message 4 in Figure 1). The MA_k negotiates with several EAs to select among them the ones that are the most promising, at the moment, to satisfy its actual need. This negotiation results in process of multiple rounds (Oliveira and Rocha 2000) where the MA_k plays the role of coordinator. The MA_k proposals' evaluation is done by comparing between them all the proposals received from the several EAs.

Enterprise Agent (EA) represents a specific enterprise. Each EA sends an announcement message describing its competencies in the market according to the established ontology (i.e., message 2 in Figure 1). A particular EA_i will compete with other EAs that have similar competencies to be a partner of the VE. As explained before, the EA' competencies (components) are identified by a list of attributes, that includes the EA own preferences and constraints related to those attributes. The structure used to identify an attribute Atb_i is composed of the attribute's values ordered by preference (Val_Atb_i) and also the dependencies associated with the different attribute's values (Dep_i). These dependencies may be of three types: time, event and value. $Dep_i=\{\{Dept_i\}, \{Depe_i\}, \{Depv_i\}\}$, where time dependencies constrains the attribute's values in specified time intervals, event dependencies constrains the attribute's values when some specified event happen, and the value dependencies constrains the attribute's values to other attributes' values of other components. During the negotiation process that leads to the VE formation, the EA_i formulates proposals in an adaptive way, learning with qualitative feedbacks formulated by the MA_k in previous negotiation rounds.

2.2 Q-Negotiation and Distributed Constraint Satisfaction Algorithm

In the VE formation process, the selection of the enterprise partners, which will integrate the VE, is done through a negotiation algorithm called Q-Negotiation. The Q-Negotiation algorithm uses a reinforcement learning strategy based in Q-learning (Rocha and Oliveira, 2001) for the formulation of new proposals.

The use of a reinforcement learning algorithm seems to be appropriate in this specific scenario, since enterprise agents evolve in an, at least, partially unknown environment. In particular, Q-learning enables on-line learning, which is an important capability for B2B negotiations where agents may effectively learn in a continuous way during all the negotiation process, with information extracted from each negotiation round, and not only in the end of the negotiation. The adaptation of the Q-learning algorithm to our specific scenario, that is, the VE formation, leads to the inclusion of two important features (the reward value calculation and the decrement of the exploration space) detailed in (Rocha and Oliveira, 2001).

One of the requirements for the negotiation protocol used in ForEV, besides dealing with attributes intra-dependencies, is the capability to deal with attribute's inter-dependencies. This is an important requirement to be considered in our scenario, because in the VE formation process interdependent negotiations take place simultaneously, and proposals received from different enterprise agents may have incompatible dependencies.

Our distributed dependencies satisfaction algorithm, besides reaching the optimal solution, keeps agent's information as much as possible private. Each agent involved in the distributed dependent problem resolution should know all possible values for its own dependent attributes. Agents will then exchange among them alternative values for the dependent attributes, in order to approach an agreement. As in any iterative negotiation process, agents start the negotiation by proposing its optimal solution and, in the next rounds start trying to reach a consensus. A more detailed description of this algorithm may be found in (Rocha and Oliveira, 2001).

Since enterprises may be formally unknown to each other and represented by means of heterogeneous agents, ForEV have been enhanced with new functionalities that make those heterogeneous communicating agents to understand each other no matter the differences in their own ontologies.

3 ONTOLOGIES

Ontologies are a popular research topic in various communities such as knowledge engineering, natural language processing, cooperative information systems, intelligent information integration, and knowledge management. The reason for ontologies being so popular is in large part due to what they promise: a shared and common understanding of some domain that can be communicated across people and computers (Duineveld et al., 1999).

Agents may use different ontologies to represent their view of a domain. Each domain may be specified in many different ways and this ontology mismatch is a question under intensive research.

(Wache et al., 2001) presents three different directions on how to employ the ontologies: (i) single ontology approach, (ii) multiple ontology approach, (iii) hybrid ontology approach. Figures 2, 3 and 4 illustrate the three architectures derived from these approaches:

Single ontology approach: uses a global ontology providing a shared vocabulary for the specification of the domain semantics. All information sources are related to a global ontology. The global ontology may also be a combination of several specialized ontologies.

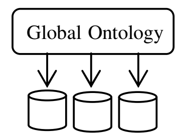

Figure 2 - Single ontology approach

Multiple ontology approach: each information source is described by its own ontology. In principle, the "source ontology" may be a combination of several other ontologies but it may not be assumed that the different "source ontologies" share the same vocabulary.

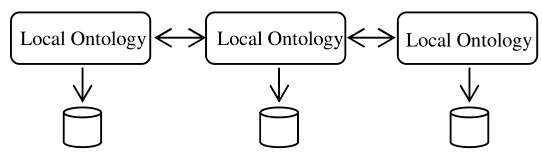

Figure 3 - Multiple ontology approach

Hybrid ontology vocabulary: similar to multiple ontology approach the semantics of each source is described by its own ontology. But in order to make the source ontologies comparable to each other they are built upon one global shared vocabulary. The shared vocabulary contains basic terms of the domain.

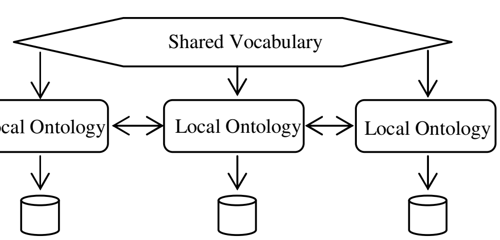

Figure 4 - Hybrid ontology approach

In this work, we are using the multiple ontology approach where each agent playing a specific role, explores its own ontology. It is a decentralized and distributed approach according to our Multi-Agent System architecture (Malucelli and Oliveira, 2003).

3.1 Ontologies and Business Transactions

Ontologies provide support in integrating heterogeneous and distributed information sources. E-commerce is currently facing revolutionary changes: Marketplaces are enabling new kinds of services interactions between suppliers and buyers (Fensel, 2001). However, how can one ensure that suppliers and buyers have the same understanding regarding the issues that are subject to the negotiation?

Ontology is required to ensure that agents are negotiating about the very same item/good/service. Products heterogeneity is a critical impediment to efficient business information exchange. Specifying a simple product like a compact disc is relatively easy and there is a chance of always finding similarities in the description, but specifying a more complex product like a car or a plane may be really tough work.

In e-commerce activities involving interactions among different sellers (B2B model) or between one buyer and multiple sellers (consumer-to-business model), a common ontology is crucial (Ng and Lim, 2001). It is not sure that all the agents will use a common ontology, usually, in a decentralized and distributed approach, each agent has its specific, private ontology and it may not fully understand other agent's ontology once different representations and terminologies may exist for the same concepts and there is no formal mapping procedure available.

3.2 Interoperability Problem

In a decentralized and distributed approach, interoperability refers to the way we communicate with people and software agents, the problems which hamper the communication and collaboration between agents. Our objective is to help in the interoperability problem, enhancing agents with abilities to provide services to and accept services from other agents, and to use these services so exchanged to enable agents to effectively negotiate together.

By making the enterprise agents interoperable, we enable them to meet the basic requirement for multilateral cooperation. In ForEV platform, the enterprise agents have homogeneous structures as well as the same domain of discourse. However, in real-life situations, real problems involve heterogeneity. This kind of problems makes the negotiation process difficult for the VE partners' selection, and for the cooperation process in the VE.

There are two major types of cooperative interaction which may be identified in a Multi-Agent System: the first concerns which agents perform which tasks (the task allocation problem) and the second concerns the sharing of information (both results and observations on the outside world) between agents. Purpose heterogeneity is primarily concerned with the former type and semantic heterogeneity with the latter (Roda, et. al, 1991).

The use of a common ontology guarantees the consistency (an expression has the same meaning for all the agents) and the compatibility (a concept is specified by the same expression, for any agent) of the shared information in the system (Macedo, 2001). However, ontologies are often developed by several persons and continue to evolve over time. Moreover, domain changes adaptations to different tasks, or changes in the conceptualisation might cause modifications on the ontology. This will likely cause incompatibilities (Klein et al., 2002). Some research has been done trying to solve the problem of interoperability (Klein et. al, 2002), (Welty and Guarino, 2001), (Rodríguez and Egenhofer, 2003), using semantic relations lexical taxonomy, semantic similarities, linguistic similarities of terms, taxonomic relationships, and using text information.

3.3 Agents' Ontology Creation

In the last years, the number of tools for building ontologies developed both by the American and European research communities was large. Whenever a new ontology is going to be built, several basic questions arise related to the tools to be used (Gómez-Pérez, 2002). Several development tools are similar and there is not a complete tool for all the ontology life cycle. A good selection depends on the necessity of the user, and thus the user has to read about the characteristics (description, architecture, interoperability, representation support, inference services, and usability) to choose the tool, which is the most suitable for his objectives.

Ontology creation for our particular domain (cars' assembling domain) involved literature search on cars' assembling domain and discussion with experts. After careful consideration and test of several different ontology building tools, we have selected the appropriated ones. First we have modelled our ontology by means of UML and then an ontology-building tool has been used.

In this work the ontologies have been developed using the Protégé (Gennari et al., 2002), WebODE (Arpírez et al., 2003) and OntoEdit (Sure et al., 2002) tools. We are using a decentralized and distributed approach according to our Multi-Agent System architecture, where each agent explores its own ontology created by means of different tools and knowledge structure.

4 ONTOLOGY-BASED SERVICES

A central point of the agents paradigm of software development is that communities of agents are much more powerful than any individual agent, which immediately raises the necessity for interoperable agent systems.

Consider the following simple negotiation example: the market agent, representing the customer, needs to buy a "wheel" (a simple machine consisting of a circular frame with spokes (or a solid disc) that can rotate on a shaft or axle in vehicles) and an enterprise agent offers "wheel" (a handwheel that is used for steering). These two components belong to the same cars' domain, they are syntactically the same but semantically different, and probably the agents will negotiate under these components. Otherwise, when the market agent needs to buy "tyre" (a thick rubber ring, often filled with air, which is fitted around the outer edge of the wheel of a vehicle…) an enterprise agent does not offer the component because it sells "tire" (a thick rubber ring, often filled with air, which is fitted around the outer edge of the wheel of a vehicle…). In this case, both words are also in the same cars' domain, but they are syntactically different and semantically the same. In the first case the agents will lose time negotiating under different products and in the second example, when the negotiation could be fruitful, they will not negotiate because they do not understand each other.

Sometimes also, agents are negotiating a good/product/service using different attributes. The market agent, for example, needs car's motor and announces the basic requirements such as power, consumption, number of cylinders, torque, quantity, delivery time, injection and transmission. The enterprise agent offers the car's motor using characteristics as price, delivery time, quantity, cylinder piston position, motor type and power. Both agents have to negotiate using the same characteristics and some requirements are even mandatory. In this example, it is essential to describe power, torque, consumption and number of cylinder, because if one of these characteristics is not the same, the other characteristics do not matter.

Besides these problems, other problems may occur like using different currencies to denote different prices, different units to represent measurement, a different structural properties representations and mutual dependencies between attributes. These problems may make the negotiation process even harder.

In order to help the resolution of potential incompatibilities as the ones explained before, some ontology-based services are proposed: (i) definition of each product attribute's dependencies, (ii) abilities to translate terms between two different ontologies, (iii) capability of learning with the ontology-based services already provided, so that it could be possible to use this information in a future negotiation, (iv) converting values when agents work with different metrics, (v) advising about mandatory or different attributes of items under negotiation.

An Ontology-based Services Agent is created and it has a basic local ontology. The Ontology-based Services Agent monitors all the communication and negotiation. When Market Agent sends an announcement asking for some item/good required, all the Enterprise Agents may or may not understand the description (item/good) announced. If the enterprise agents understand the item under negotiation, and if it is of its interest, it may formulate a proposal and the negotiation process starts.

During the negotiation new interoperable problems may occur. The agents involved in the negotiation may ask to Ontology-based Services Agent for helping whenever they need. However, Ontology-based Services Agent will be helping even without being solicited. If some problem is detected, in order to help the resolution of the incompatibility, the Ontology-based Services Agent exchange messages with the involved agents asking for more information, consulting the local ontology and web services whenever it is necessary.

4.1 Integration of Ontology-based Services Agent with ForEV

In ForEV platform, as explained in the Section 2.1, the Register Agent (RA) is responsible for: (i) the local market creation and maintenance, where the multiple agents meet each other and interact, and (ii) creating and presenting the domain ontology for all the participants. Now, ForEV has been enhanced with new functionalities that make those heterogeneous communicating agents to understand each other no matter the differences in their own ontologies. RA is still responsible for the local market creation and maintenance, however instead of a common ontology, ForEV accepts heterogeneous agents including their own specific ontology, which may be just in correspondence through the new Ontology-based Services Agent.

This new Ontology-based Services Agent is integrated in ForEV architecture to help in the VE formation process, providing useful advices on how to better negotiate specific items and how different terms may be understood as equivalent. It is up to this Ontology-based Services Agent to make it possible negotiations in the Multi-Agent System and finally lead to acceptable and meaningful agreements.

Ontology-based Services Agent keeps monitoring the whole agents interaction just in time, without needing a previous and tedious complete ontology mapping process. Each agent (market or enterprise) has its own architecture and functionalities (some developer will design and build the ontology with some tool and, later, the agent will access the generated file/database).

The Ontology-based Services Agent is monitoring the negotiation and communication, accessing a local ontology and web services whenever it is necessary and updating the local ontology whenever new concepts are discovered, this way the Ontology-based Services Agent may use previous knowledge in the next negotiation rounds.

5 IMPLEMENTATION

In our proposed architecture each agent may be geographically distant exploring its own ontology, built by different developers.

We are using Java technologies such as: (i) Applet/Servlet to create a protected communication channel between the client machine and the server. It will be used to send information about the user and the agent to the server databank, (ii) RMI (Remote Method Invocation) to access the agent object and use its methods through the applet, (iii) JATLite to implement the communications infrastructure, which has specific facilities to messages passing and queueing treatment using KQML language, (iv) SOAP/WSDL for the ontology agent to use distant services on the Web.

The central component of JATLite platform is the ARM (Agent Message Router) application, where all the agents in the system have to register in. The AMR stores the information about all the agents with their identity (name and password) and localization (machine and physical location). AMR is the responsible for all the distributed system communication management. KQML (Knowledge Query and Manipulation) is the language used for communication.

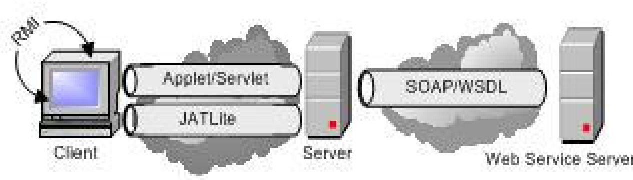

Figure 5 – Technologies Platform

6 CONCLUSION

In this paper we have presented the ForEV agent-based platform, which have been developed aiming to facilitate the partners' selection automatic process in the context of Virtual Enterprise formation. ForEV platform has implemented the Q-Negotiation algorithm, which includes appropriate features for dealing with the specific requirements of the VE formation scenario. An important requirement in this process, is that information must be kept private to individual enterprises, since they are competitive by nature and do not want to reveal their market strategy to others. The Q-Negotiation algorithm has the ability to maintain information private and, at the same time, it includes the capability to evaluate multi-attribute proposals, to guide learning during the negotiation process, and to resolve attributes' mutual inter dependencies.

The presence of several heterogeneous customer and supplier agents makes it necessary ontologies to ensure that agents are negotiating about exactly the same item. One of the problems of using different ontologies is that there exist different representations and terminologies and on the other hand, there is no formal mapping available between high-level ontologies. Product description heterogeneity is a critical impediment to efficient business information exchange.

Several problems involved in the resolution of interoperability are difficult to be solved, at least nowadays, but it is important to look for possible ways to resolve parts of the problem. Many different ontology technologies are already available (methodologies, tools and languages), and the future points towards the use of these technologies and to develop functionalities to improve the business information exchange. Therefore, we have proposed Ontology-based Services to enhance B2B transactions given support in the negotiation needed for Virtual Enterprise formation process. In our proposed architecture each agent may be geographically distant, exploring its own ontology, built up by using different ontology technologies. In our experimental scenario ontologies were built using Protégé, WebODE, and OntoEdit.

The Ontology-based Services Agent proposed here, monitors agents communication and negotiation, accessing a local ontology and web services to help whenever the negotiation process is hard. This may be caused by problems like agents using different attributes to negotiate the same kind of product, different currencies to denote different prices, different units to represent measurement or a different structural property representations. The local ontology will be updated whenever new concepts are discovered, enabling the Ontology-based Services Agent to use previous knowledge in the next negotiation rounds.

REFERENCES

Ströbel, M., 2001. *Communication Design for Electronic Negotiations on the Basis of XML Schema*. In Proceedings of the Tenth International Conference on World Wide Web. ACM Press. Hong-Kong. pgs 9-20.

Obrst, L., Liu, H. and Wray, R, 2003. *Ontologies for Corporate Web Applications*. AI Magazine. American Association for Artificial Intelligence. vol 24 (3). Fall.

Oliveira, E. and Rocha, A.P., 2000. *Agents advanced features for negotiation in Electronic Commerce and Virtual Organisation formation process*, In: Dignum, F., Serra, C (eds.): Agent Mediated Electronic Commerce, the European Agentlink Perspectives. LNAI, vol 1991. Springer-Verlag, Junho. 77-96.

Rocha, A.P. and Oliveira, E., 2001. *Electronic Institutions as a framework for Agents' Negotiation and mutual Commitment*. In Proceeding of EPIA2001, 10th Portuguese Conference on Artificial Intelligence, LNAI, Springer-Verlag, Portugal.

Duineveld, A.J., Stoter, R., Weiden, M.R., Kenepa, B., Benjamins, V.R., 1999. *WonderTools? A comparative study of ontological engineering tools*. In Proceedings of the 12th Banff Knowledge Acquisition for Knowledge-Based Systems Workshop.

Wache, H., Vögele, T., Visser, U., Stuckenschmidt, H., Schuster, G., Neumann and H., Hübner, S., 2001. *Ontology-Based Integration of Information-A Survey of Existing Approaches*. In Proceedings of the 17th International Joint Conference on Artificial Intelligence (IJCAI-01). Workshop: Ontologies and Information Sharing, Seattle, USA.

Malucelli, A., Oliveira, E., 2003. *Ontology-Services to Facilitate Agents' Interoperability*. In Proceedings of the Sixth Pacific Rim International Workshop on Multi-Agents (PRIMA 2003). Eds. Jaeho Lee, Mike Barley, Springer-Verlag. LNAI 2891. pgs 170-181, Korea. Novembro.

Fensel, D., 2001. *Ontologies and Electronic Commerce.* IEEE Intelligent Systems. pg 8. January/February.

Ng, W.K, Lim, E.P., 2001. *Standardization and Integration in Business-to-Business Electronic Commerce*. IEEE Intelligent Systems. pgs12-14. January/February. 2001.

Roda, C., Jennings, N.R. and Mamdani, E.H., 1991. *The impact of heterogeneity on cooperating agents*. In Proceedings of AAAI Workshop on Cooperation among Heterogeneous Intelligent Systems, Anaheim, USA.

Macedo, A.P, 2001. *Metodologias de Negociação em Sistemas Multi-Agentes para Empresas Virtuais. Tese de Doutoramento*, Faculdade de Engenharia, Universidade do Porto.

Klein, M., Kiryakov, A. Ognyanoff, D. and Fensel, D., 2002. *Finding and specifying relations between ontology versions*. In Proceedings of the ECAI-02 Workshop on Ontologies and Semantic Interoperability. Lyon, July 22.

Welty, C. and Guarino, N., 2001. *Supporting ontological analysis of taxonomic relationships*. Data&Knowledge Engineering 39 (2001) 51-74.

Rodríguez, M.A. and Egenhofer, M.J., 2003. *Determining Semantic Similarity Among Entity Classes from Different Ontologies*. IEEE Transactions on Knowledge and Data Engineering 15(2) 442-456.

Gómez-Pérez, A., 2002. *Ontology-based information exchange for knowledge management and electronic commerce*. IST-2000-29243. Deliverable 1.3: A survey on ontology tools. Chapter 2. pgs 13-34. 31st may.

Gennari, J., Musen, M.A., Fergerson, R.W., Grosso, W.E., Crubézy, M., Eriksson, H., Noy, N. F. and Tu, S. W., 2002. *The Evolution of Protégé: An Environment for Knowledge-Based Systems Development The Evolution of Protégé: An Environment for Knowledge-Based Systems Development*. Technical Report. SMI Report Number: SMI-2002-0943

Arpírez, J. C.. Corcho, O., Fernández-López, M. and Gómez-Pérez, A., 2003. *WebODE in a nutshell*. AI Magazine 24(3):37-48. Fall.

Sure, Y., Erdmann, M., Angele, J., Staab, S., Studer, R. and Wenke, D., 2002. *OntoEdit: Collaborative Ontology Development for the Semantic Web*. In Proceedings of the First International Semantic Web Conference (ISWC 2002), June 9-12 Sardinia, Italia.