ONTOLOGICAL APPROACH TO DOMAIN KNOWLEDGE REPRESENTATION FOR INFORMATION RETRIEVAL IN MULTIAGENT SYSTEMS

Anatoly Gladun, Julia Rogushina, Victor Shtonda

Abstract. An ontological representation of buyer interests' knowledge in process of e-commerce is proposed to use. It makes it more efficient to make a search of the most appropriate sellers via multiagent systems. An algorithm of a comparison of buyer ontology with one of e-shops (the taxonomies) and an e-commerce multiagent system are realised using ontology of information retrieval in distributed environment.

Keywords: ontology, e-commerce, multiagent system.

ACM Classification Keywords: I.2.4 Knowledge Representation Formalisms and Methods

Introduction

Now we are participants of the evolution of the post-industrial society to the information one where a prior tendency is directed to an accumulation and an effective use of knowledge and information resources.

Great perspectives in the development of commodity market and services by Internet market make an impression even to specialists in information technologies (IT). The technical progress in this area renders active a world economy globalization and makes e-commerce the more attractive object to investments.

However, existent alterations result in a whole series of new problems. Variety of goods and services and lots and lots of offers as well as high dynamics of market changes bring to challenging increasing of processing complexity and laboriousness in the network either of sellers or buyers. It takes a lot of time and thereby increases the cost of e-commerce services.

Only the fundamental change of the Internet information processing concept allows to substantially answering customer queries, efficiently respond to varying demands and adapt flexibly to market circumstances.

The entry of Ukraine in the global information space requires deciding a multifold problem of automation of modern business applications. By electronic business (e-business) they understand all forms of electronic business activities including such as e-commerce, e-consulting, e-publishing etc. E-commerce is a special case of e-business. E-commerce joins the various forms of the goods and services trade by use of electronic means, including Internet. The order of the goods in e-commerce is carried out by telecommunications, and accounts between buyer and seller are realized by electronic payment means [1].

Improvement of the e-business tasks efficiency requires a further development of methods of the business-processes automation. E-commerce systems have to provide the user access to the information on goods that is represented in an electronic form as well as a fast information search in a network environment. Transaction complexity is very high due to a dynamic quality and a lot of information to be accessed to users over the Internet. An industrial software development for e-commerce requires creating and using the proper models, standards, languages and formats oriented on knowledge processing. For solving these problems, the agent-oriented technologies are successfully applied based on the use of intelligent software agents (SA).

Related Work. E-commerce Support Systems

Now a lot of various software products with different complexity levels are design for the e-commerce support. Modelling of real applications has to represent the multiplicity of real world business processes. It seems to be evident that only an intellectualization of such means can relieve user of necessity to carry out the oft-recurring actions.

One of the most perspective approaches in e-commerce is now based on SA and multiagent systems (MAS). The main problem in its practical application deals with integration of complex intelligent capabilities in mobile SA's.

SA is software that has some specific features and intend for a simplification of the user dialog with a complex dynamic information environment. An agent works autonomously and for a long time in an actual or simulated environment in cooperation with other agents and processes [2]. They inhabit a complex and dynamic environment with which it may interact to achieve a given set of goals. An intelligent SA can reason in a rational manner and report back result to humans. In the ideal variant an intelligent SA that works for a long time can learn by its own experience. Besides, when coexisting with other agents and processes the SA have to be able to communicate and to cooperate in a team work [3,4].

We have analysed a number of e-commerce agents. PersonaLogic [5] filters out the list of goods that satisfy to user restrictions. Firefly [6] selects the goods by estimations of consumer's preference. BargainFinder [6] is a virtual agent of purchases that can be able to estimate their prices and their suitability for the user. It represents a consumer question in parallel to a group of on-line sellers by filling the form on each site. Kasbah [7] is an on-line MAS for transactions of the "consumer – to - consumer" type. If user wants to sell or buy some goods she/he creates an agent, sets to it the main strategic direction and sends it to the centralized agent market. The agents Kasbah proactively search for potential buyers or sellers and negotiate with them on behalf of their founders. Tete-a-Tete [8] is used for intermediary and negotiation by providing requirements either of sellers or buyers.

For retrieval of a product a buyer chooses a set of the good characteristics that are of interest of her/him. If any goods that satisfy all requirements aren't found then user has notice of it, or the list of the goods that partially satisfy to these queries is generated. The ranking principles of retrieval results frequently are not clear to the user. The customer does not receive neither a precise review of results, nor propositions for further research.

The situation would be better if some closest to her/his needs alternatives were proposed to buyer. But for this purpose the system should process knowledge about the concrete customer.

Unfortunately, the most part of the existing e-commerce systems do not provide a general interaction language, a standard domain description as well as adaptability, learning ability, and personalization. E-commerce agents created by different developers are not capable to cooperate with each other. Besides, many terms and expressions are extremely ambiguous, and their meanings depend on the user subject domain.

Problem Statement

When only key words are applied by user for informational retrieval then SA have not knowledge about domain that interested the user. SA is able to an independent knowledge acquisition only after the communication with user for a long time. Therefore it is necessary to find means of a formalized representation for such domain knowledge and to develop the algorithms of knowledge processing to make the agents more effective in goods and services retrieval.

We propose to employ the ontologies for a description of a domain being interesting for a particular user. Ontology is an universal tool for a representation of distributed and heterogeneous knowledge bases. It allows to avoid disagreements in use of a terminology and to help agents in establishing a correspondence between seller offers and buyer requirements. It is expected that sellers propose an ontological representation of knowledge about the offered goods

Ontological Representation of Knowledge

Ontology is a knowledge represented on the basis of conceptualization that intends a description of object and concept sets and relations between them. Formally, ontology consists of the terms organized in taxonomy, their definitions and attributes, and also connected with them axioms and rules of inference.

Ontology is a semantic basis in a content description. It is a logic theory that consists of the dictionary and the set of statements in some language of logic [10]. It can be applied for communications between the people and software agents.

Frequently, ontology has the form of the first order logic theory where the terms of the dictionary are names of unary and binary predicates. In a simple case, ontology describes only the hierarchy of concepts that are connected by categorization relations. As for more complex cases the axioms that represent other relations between concepts and restrict their interpretation are added to the ontology. Ontology is a specific knowledge base that uses the dictionary containing standard term meanings. It describes facts that are always true within a certain community.

A formal model of an ontology O is an ordered triple O = < X, R, F >, where X is a finite set of subject domain concepts of the ontology; R is a finite set of relations between the concepts of the given subject domain; F is a finite set of interpretation functions that are given on concepts and the relations of the ontology O.

Nowadays, a lot of ontology representation languages (e.g., DAML-OIL, OWL [11]), free distributed software tools for an ontology design (e.g., Protégé [12], OntoEdit [13], OilEd [14]) and for an ontology analysis (mapping, alignment and merging, e.g., PROMPT [15], Chimaera [16], OntoMerge) are developed.

The tools of ontology integration help users to find similarity and difference between initial ontologies and create resulting ontology that contains elements of initial ontologies. For this purpose, they automatically determine conformity between the concepts in initial ontologies or provide environment where the user can easily find and determine these conformities. These tools are known as tools of ontology mapping, alignment and merging because of they carry out similar operations.

Buyer Ontology Design

Large ontology, such as CYC, is created on the base of the abstract and much generalized description of domain concepts and their relations. The main purpose of the project CYC is to construct finally the knowledge base of all general concepts that will be accessible to various software. But in practice every user prefers the own context for representation of the terms that depends on the situation, the user task and the user model of the world. Therefore frequently huge ontology containing the description of all world is not necessary to user.

It is obvious that the ontology design is an enough complex and laborious process. User has to represent subject domain precisely and structurally be able to work with the appropriate software.

Besides it is expedient only in a case of buyer carries out relatively the same purchases during the long period of time (experts in purchases in small and medium business - B2C, B2B) and in the large volumes (for example, supply departments of large organizations - B2B, state purchases - B2G).

The advanced user creates ontology of that area that deals with her/his order and then uses this ontology for retrieval of most suitable seller. To increase the retrieval relevance user has to describe her/his knowledge and beliefs about domain objects, their relations and rules of their transformation on base of standard means of ontology representation. It provides independence of the user of the applied software because the same ontology can be processed by various e-commerce systems.

In this approach we are oriented on the simplicity and compactness of the ontology that is created by the user. The set of functions of interpretation is empty - F=∅, and R - set of the relations between domain concepts contains only a few base relations ("to be an element", "to have the price", "to have property", "synonym", etc.).

Seller ontologies also are quite simple. Even if they contain a lot of concepts, their structure is enough standard. Usually ontology that describes goods of e-shop are simple taxonomies - hierarchical systems of concepts connected by the relation "to be a class element", i.e. $O=T^0=<X, \{\text{"to be a class element"}\},\varnothing>$.

Ontologies allow determining a common terminology for the communications between the users (either people or software entities). The user query is supplemented by ontological information about corresponding subject domain (fig.1).

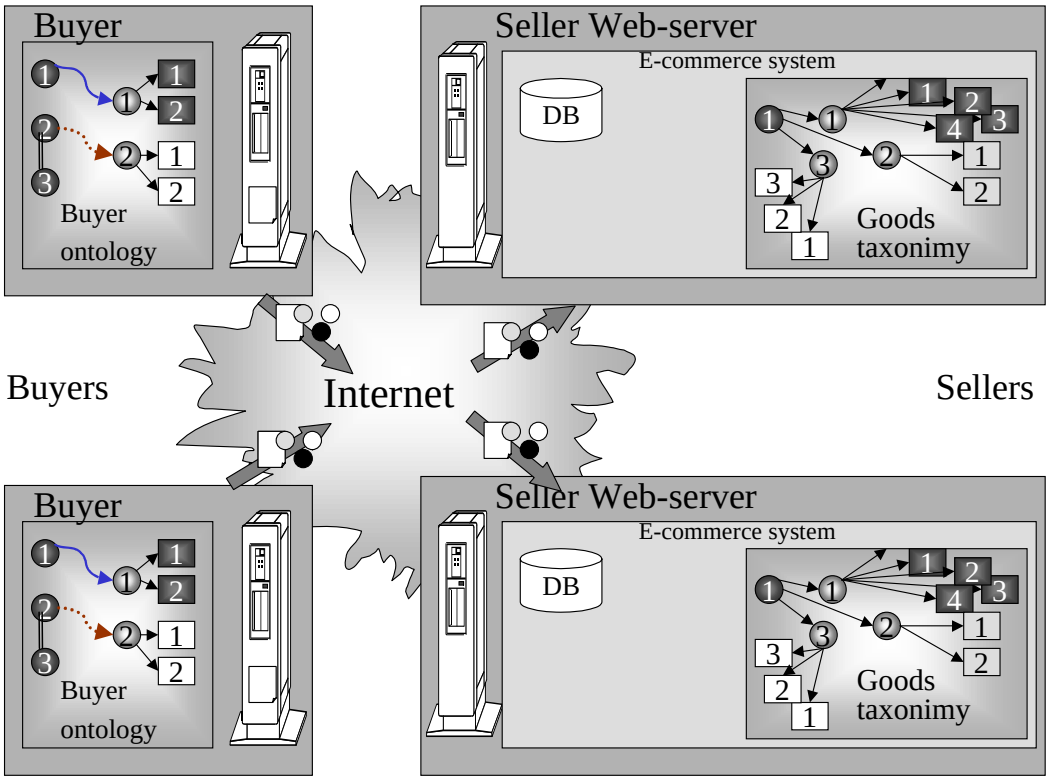

Figure 1. Ontological information use for information retrieval of sellers by buyers

Comparison of Buyer and Seller Ontologies

We use ontological representation of knowledge in prototype of e-commerce MAS for personification of the buyer and seller agents: if other conditions are equal the advantages are given to the seller whose ontology contains more terms from buyer ontology.

The ontology comparison requires various methods, methodologies and technologies that are necessary for an effective use of ontological knowledge. Each domain ontology covers the certain knowledge aspects and uses a different terminology. Special ontologies should be created for representation of connection between the various terminologies and styles of modeling that are used in ontologies of some domain.

Today a lot of software tools are designed for these purposes. For example, in the project Sesame the comparison of the ontology versions represented in RDF format and analysis of these changes is provided. But such software is too intricate for the users who are not specializing in IT.

We propose to compare ontologies in the following way: for pair of ontologies O1 = < X1, R1, F1 >, and O2= < X2, R2, F2 > the valuation function f (O1, O2) is built. This function determines their proximity measure. All pairs (x1 : x1 $\in$X1; x2 : x2$\in$X2) are analyzed. Thus the following factors are taken into consideration:

- term belongs to both ontologies - $x_1 \in X_1 \cap X_1$, - $x_2 \in X_1 \cap X_1$;
- pair of terms x_1 and x_2 belongs to both ontologies and they are in the same relation $r \in R_1 \cap R_1$;
- pair of terms belong to both ontologies by they are in the different relations of the same type (for example, in the hierarchical relations $r_1 \in R_1$ and $r_2 \in R_2$);
- pair of terms belongs to both ontologies by they are in the relations of different types (for example, in the hierarchical relation $r_1 \in R_1$ and synonymy relation $r_2 \in R_2$).

At a preliminary stage of ontology comparison (fig. 2) the set of elements - domain concepts that belong to both ontologies - is formed. Then all relations between these concepts are tested.

The user determines the type of each relation in ontology. In seller ontology such problem does not arise because the unique hierarchical relation is used.

The coefficients that determine the weight of the various factors depend on domain specificity and are determined by the user. In the simplest case only the first factor is taken into consideration.

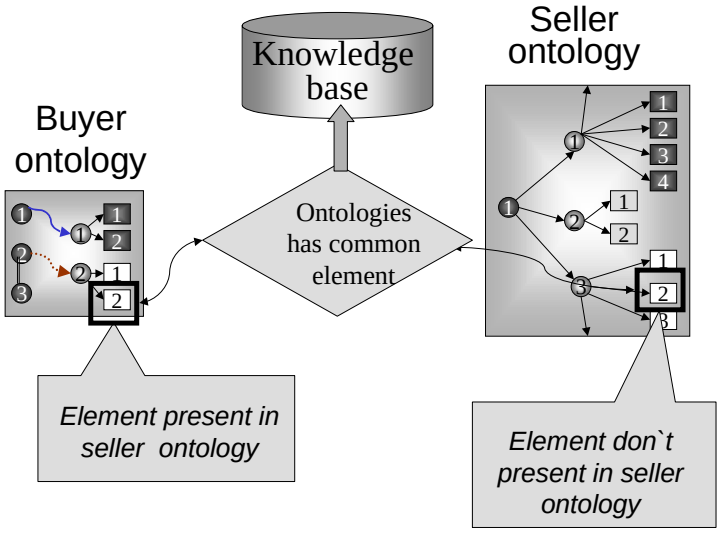

Figure 2. Preliminary stage of ontology comparison - retrieval of elements that belong to both ontologies

Prototype Implementation

In e-commerce system three interconnected subsystems are allocated: trade, dialogue management and ontology-based search of the goods and services. In a trade subsystem there can be agents of the goods and orders, and also the agents of sellers and buyers, warehouse, suppliers etc. Agents of the goods and orders negotiate with discounts strategies for patrons, wholesales, overstocking of the warehouse etc.

Some buyer agents (potential competitors) can join their orders for profit earning by the greater discount, i.e. pass from a competition to cooperation.

In the subsystem of dialogue management it is necessary to create system that returns the results of agent negotiations. The ontological subsystem provides intelligent search in distributed environment of the goods relevant for buyer.

On the basis of the existing e-commerce MAS analysis [5-9] we formulate the requirements to software realization:

1. Assurance of code portability on various platforms (UNIX, LINUX, Windows).

2. Availability of other platforms in a network. This requirement is a sequential of previous one. The mobile agents should carry out the work in heterogeneous computer environment.

3. Support of network interaction. Besides operations directly connected to moving between agent servers, the agent should have means for the communications with other agents and access to the removed resources. Therefore support of network services should include a wide spectrum of opportunities (service of names, RPC, OLE, CORBA, RMI etc.).

4. Multiflow processing. For realization of synchronous execution of several actions MAS should include support of parallel agent function execution and support of synchronization means.
5. Safety. The mobile agents coming from the network can contain potentially dangerous, harmful code. Therefore system should support safety means that are sufficient for its normal work.

For development of logic model of MAS we use UML language. The MAS structure includes: the interface module; the user interaction module (event handler); the main module MAS - module of coordination and management (according to the problem put by); ontological data processing module (sorting, filtration, search etc.); the module that returns the results to user (as a log-file - messages on the user interface).

All intelligent agents of MAS are developed on a basis of Java class CIAgent which is in details described in [17]. FacilitatorAgent (agent - intermediary) operates the market, BuyerAgents (agents - buyer) and SellerAgents (agents - sellers) are used for interaction inside this market are developed on a basis of Java. MAS contains a number of buyer and seller agents that differ, first of all, by complexity of their negotiation strategy. The negotiations are begun by simple logic rules (in the terms if-then-else), and then pass to methods of rule formation that are based on the acquired facts.

The KQML language concretizes a format and contents of interactions between sellers and buyers. The procedure BuySellMessages describes negotiation between seller and buyer in process of the market transaction. Buyer and seller never communicate directly and use for this purpose FacilitatorAgent (agent-broker) as the intermediary in negotiation on sale and purchase. The manager of the communications (BuySelMessage) comprises the messages that should be sent to other agents. These messages by means of communication language with KQML primitives: *to make a request, to accept, to reject, to change, to offer, to inform, to request the data, to refuse* and *to confirm*. Fig.3 shows the MAC window for negotiating between the seller and buyer in process of sale.

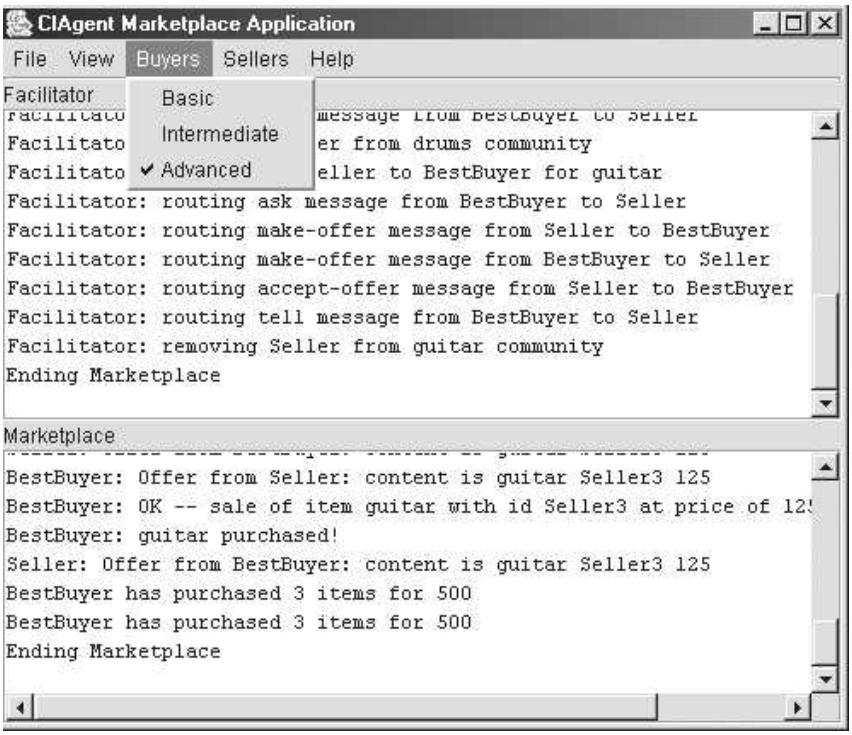

Figure. 3. MAC window for negotiating between the seller and buyer in process of sale with mediator

Conclusion

It seems to be sound to employ the ontological representation of knowledge in e-commerce for automated building of a buyer-seller common dictionary. The application of standard formats for representation of ontologies provides an interoperability of these ontologies and a possibility of their reuse for other tasks solving.

The approach proposed in this article considerably raises the retrieval relevance and allows finding offers of sellers the most favorable and appropriate to the user requirements. Besides, it stimulates sellers to build descriptions of their goods at a semantic level that is one more step to the transformation of Internet to a global distributed knowledge base.

The algorithm of comparison of buyer ontology and e-shop taxonomy is realized. E-commerce MAS that uses ontologies for informational retrieval in distributed environment is developed. The decision making module of MAS is constructed using elements of fuzzy set theory (a combination of numerical and linguistic approaches). The algorithms of the decision making allow allocating three groups of agents in a system by level of their intelligence.

The protocol of sale negotiations is described. It gives wider opportunities to control a sale process. In e-commerce, as well as in other areas, increasing efficiency is connected directly with the knowledge use in interoperable formats.

The e-commerce MAS prototype presented in this work can be apply to modeling market situations or for development of complete software products not only for e-commerce, but also for other business-applications, e.g., for electronic document interchange in corporate systems.

The e-commerce MAS prototype presented in this work is applied to modeling and studying market situations and to development of complete software products. It can be used not only in e-commerce area, but also for other business-applications, e.g., for e-learning, e-publishing, electronic document interchange in corporate systems.

Future Work

The ontology analysis is very important in the context of the Semantic Web project. The Semantic Web is an extension of the today Web where informational resources will be automatically processed taking into consideration their semantic. To generate a real semantic network, that will allow computers to combine and deduce new knowledge it is necessary to form a lot of different domain ontologies and then to order and to join them.

The ontology design is a difficult task that requires deep knowledge of the domain and, in most cases, special skills from knowledge engineering area. To facilitate a process of the ontology design it is necessary to develop a methodology that allows automating the extraction of a user's structured knowledge. If user (seller or buyer) gained wide experience of e-commerce usage than this experience can be generalized by methods of inductive and traductive inference. We have developed some original inductive algorithms for incomplete and semistructured data processing and now we intend to apply them for data mining tasks to increase the intelligence of e-commerce MAS.

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FORMING KNOWLEDGE BASES IN THE COMPUTER KNOWLEDGE BANK ON MEDICAL DIAGNOSTICS [1]

Mary Chernyakhovskaya

Abstract: Basic types of information resources for the computer knowledge bank on medical diagnostics are presented. They are observation ontology and some examples of observations bases from various fields of medicine. By the observation ontology observation bases can be formed, checked and used in the computer knowledge bank.

Keywords: computer knowledge bank on medical diagnostics, information resources, observation ontology, observations bases, observation group, observation

ACM Classification Keywords: I.2.4 Knowledge Representation Formalisms and Methods; H.2.8 Database Applications

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