

Contributions to the Study of Semantic Interoperability in Multi-Agent Environments - An Ontology Based Approach

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Abstract: This paper details the results of our work in the field of multi-agent ontology-based environment simulation. We analyze the impact of introducing some techniques for the alignment / translation / mapping of agent ontologies, which allows for collaborative understanding of distributed ontologies. In the end, we analyze the difficulties / gaps that are to be filled for an actual deployment of the technology / concept in a real life environment.

Keywords: ontology, semantic interoperability, agents.

1 Introduction

The ability to communicate depends on understanding the syntax and the semantics of a language. We used an ontology model to facilitate semantic interoperability in a simulated multi-agent environment. Current studies relieve the fact that using ontologies associated with the agents allows for building semantic-aware distributed multi-agent systems. An ontology is a formal specification for shared understanding of a domain of interest and offers the possibility of building a formal and machine manipulable model of a domain of interest. Ontologies describe entities and relations between them, classes of objects and their attributes, and are complemented by logical rules that constrain the meaning assigned to the terms. These constraints are represented by inference rules that can be used by agents to perform the reasoning on which the autonomy and proactiveness of the agents are based. Thus semantic interoperability facilitates the increase of the autonomy of agents. The reasoning process of agents in multi-agent ontology-based environments is mainly focused on the alignment of their own ontologies with ontologies exposed by other agents. Having considered the multi-agent environment as heterogeneous, we analyse the introduction of guidelines for ontology development and evolution which should facilitate ontology reuse that may underpin a usage model for ontologies.

2 Multi-agent environment

The multi-agent environment we propose is part of an e-commerce scenario where a user's agent AGU is activated to find, request and gather offers for a specific product from a series of suppliers' agents AGS1, ..., AGSn. In our implementation, the suppliers' agents (AGS agents) are published in the FIPA compliant Directory Facilitator (DF) of the JADE platform. FIPA is an IEEE Computer Society standards organization that promotes agent-based technology and the interoperability of its standards with other technologies. JADE is a software framework to develop agent applications in compliance with the FIPA specifications for interoperable intelligent multi-agent systems. We propose the implementation of a Mediator Agent (AGM) to make the interactions with the DF and to handle the negotiation process between agents.

The AGS agents (suppliers' agents) use their own ontologies. Suppliers can adhere to centralized/standardized/publicly available ontologies, can extend such ontologies based on their needs,

but can also build their own ontologies from scratch. Facing this heterogeneity of ontologies used by the AGS agents, the AGU agent has to achieve semantic interoperability to negotiate with each AGS agent. FIPA recommends using an external Ontology Agent (AGO) for handling the interoperability problems in heterogeneous multi-agent environments [9]. This agent handles the tasks of matching ontologies and translating the values of some attributes (translate notions based on their specified language, convert currencies, convert units of measure).

Figure 1 illustrates the architecture of the proposed system:

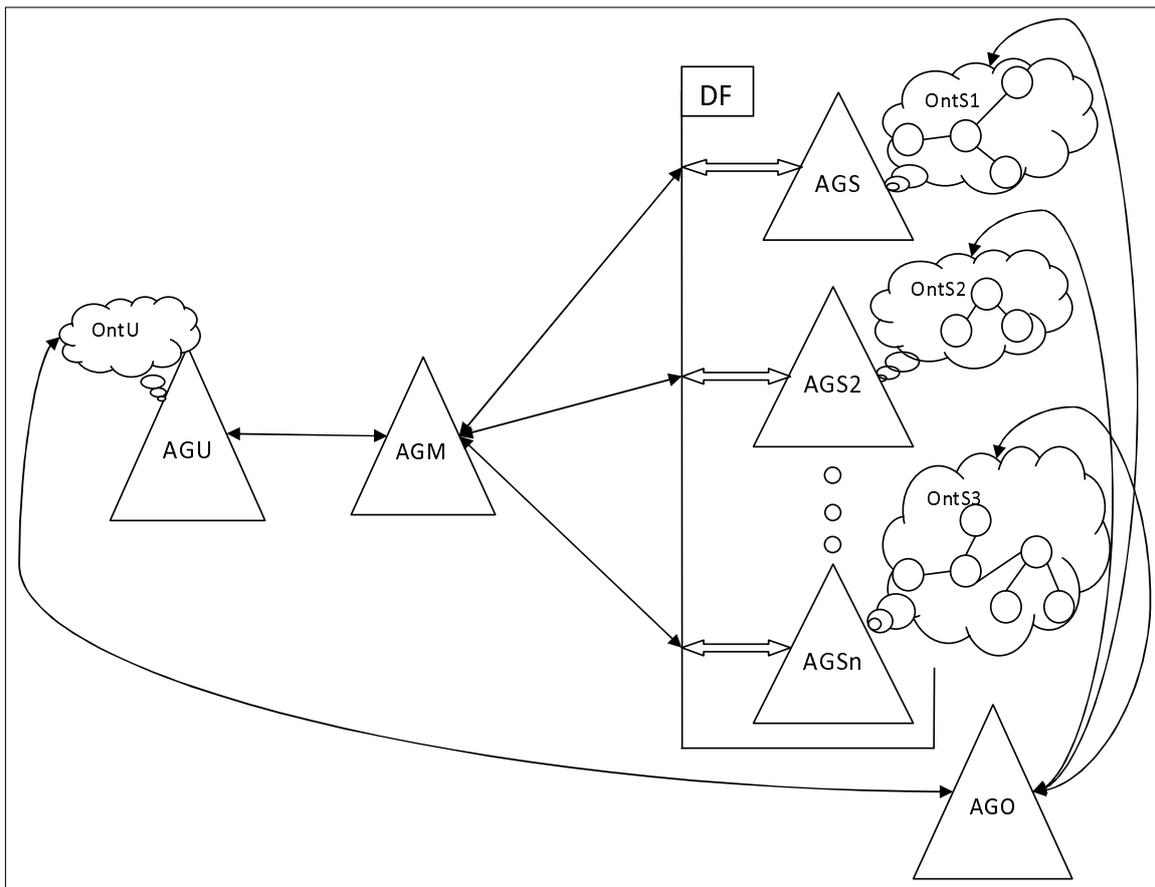


Figure 1: Ontology-based multi-agent environment

3 Ontologies

The semantical description of an entity offers a better understanding of the entity and puts the entity in a context. The idea is not necessarily to achieve the level of understanding and association to other entities that a human subject would have for that entity, but to improve the understanding of a software regarding that entity only to satisfy specific goals. The main heterogeneity problem in our simulated environment is that the agents will typically use different ontologies. Ontology-based interoperation provides a solution in environments with heterogeneous semantics. Ontologies can capture both the structure and semantics of information environments [7]. An ontology-based search agent like AGU can handle both simple keyword-based queries as well as complex queries on structured data. Figure 2 contains some sample ontologies exposed by 2 book suppliers' agents [1].

BeanGenerator tool, the re-integration in the main project and the recompiling. Any modification in an ontology represented using Java classes may also require modifications in the Java code of the agent. A solution to simplify this process is to access the Jena framework for writing ontology-based applications. This framework allows keeping the ontologies in the OWL format generated by Protégé, eliminating any further need to transform the ontology in another format. The parser of this framework has direct access to the OWL files and provides access to the classes of the ontology using Java language. Using this framework, the agent can access the instances of the classes, retrieve the value of attributes, determine subclasses etc.

5 Negotiation

The negotiation is implemented using the FIPA Contract Net Interaction Protocol [10]. The workflow for this protocol is represented in Figure 4.

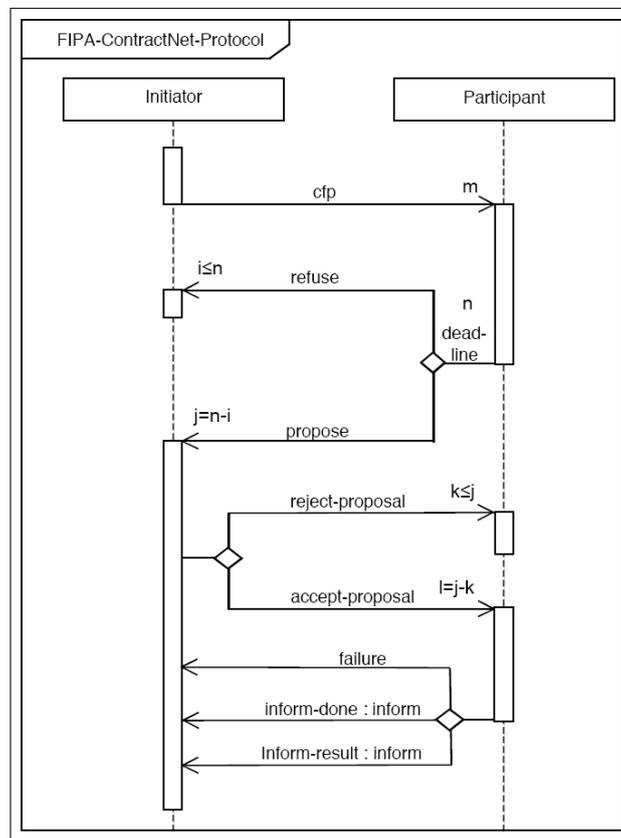


Figure 4: The workflow of the FIPA Contract Net Interaction Protocol

The semantic analysis of the ontologies takes place between the call for proposals (represented as "cfp") and the receipt of the refusals/proposals from the suppliers' agents. The semantic analysis is performed by the dedicated agent AGO. The suppliers' agents AGS1...AGSn (noted: AGS) receive the CFP. If the concept/item is understood by AGS, it starts to evaluate conditions/constraints contained in the CFP. If the conditions match, AGS returns a proposal to the AGU agent, otherwise it returns a REJECT-PROPOSAL message. The messages may be sent using predicates defined in a separate common / generalized / standard centralized ontology (OntReqSTD) specific to the process of requesting offers of products. Agents AGU and AGS could adhere to this ontology and AGS could then respond with a more descriptive message

like "AvailableOnlyWithPreOrder", "StockEmpty" rather than responding with a simple yes/no message. The types of ontologies proposed for our model are represented in Figure 5.

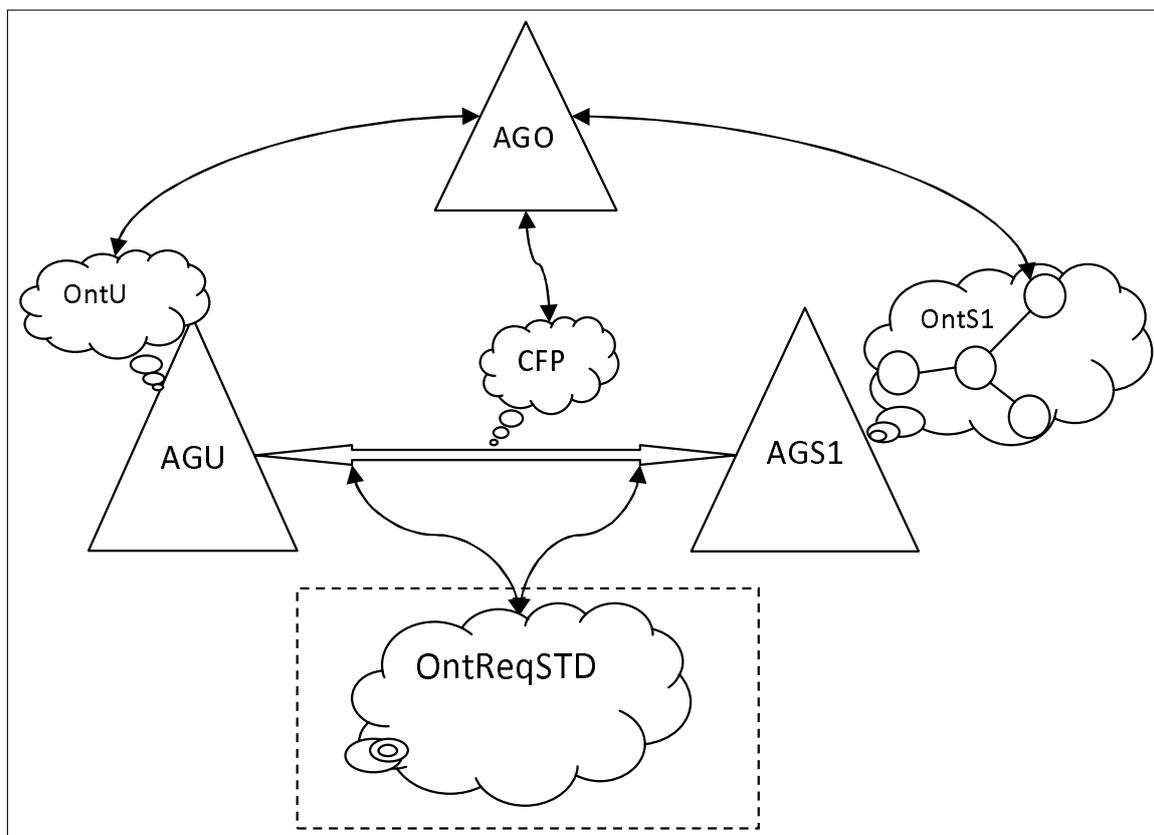


Figure 5: The role of the AGO (Ontology Agent)

Ontology matching analysis starts if the AGS does not "understand" the concepts/attributes inside the CFP. In this case, the AGS agents call the AGO agent. The AGO agent requests contact details to AGS to contact the AGU agent. Then AGO queries the AGU agent about its exposed ontology. AGO starts a matching process to obtain an alignment between the AGU request (cfp), AGU ontology (OntU) and AGS ontology. If the matching succeeds (with a high confidence mark), AGO reformulates the CFP to the AGS and the AGS may start the simple quantitative evaluation and send an answer to AGU accordingly to the result. AGO may also play the role of converting units of measure, currencies, translating notions between languages etc.) and use the values to reformulate the CFP.

6 Ontology mapping

The same concept/product may be described using different attributes, structures and relations, conducting to distinct ontologies. Even so, taking into consideration that the concept is part of a specific domain, there exists a set of common characteristics that should be mandatory when representing a specific product, like "width", "height", "material", etc. Thus lexical measures can be used to compare attributes and relations between concepts. Some of the lexical measures that can be applied to achieve ontology-matching are n-gram similarity, Hamming distance, Levenshtein distance, Jaro measure, Jaro-Winkler measure and the token-based distances like Cosine similarity, Term frequency-Inverse document frequency (TFIDF) described in [1].

The AGO agent can also make use of the language-based methods by calling external resources like Lexicons and Thesauri. WordNet [3] is such an electronic lexical database for English, based on the notion of synsets or sets of synonyms. A synset denotes a concept or a sense of a group of terms. WordNet also provides an hypernym (superconcept/subconcept) structure as well as other relations such as meronym (part of relations). It also provides textual descriptions of the concepts (gloss) containing definitions and examples. There are lots of techniques available for analyzing similarities using WordNet [4] [5].

In addition to comparing their names or identifiers, the structure of entities that can be found in ontologies can be compared. This comparison can be subdivided into a comparison of the internal structure of an entity, i.e., besides its name and annotations, its properties or, in the case of OWL ontologies, the properties which take their values in a datatype, or the comparison of the entity with other entities to which it is related.

Using these well-known techniques, the AGO agent can run a detailed analysis on the matching of the OntU and OntS ontologies. If an alignment is achieved, the AGO agent can reformulate the CFP (call for proposals) to match the OntS ontologies of the AGS agents.

7 Conclusions and the future of semantic interoperability

In this paper, we proposed a feasible implementation of a multi-agent environment which makes use of ontologies and ontology mapping to achieve semantic interoperability. The ontology-based multi-agent environments and semantic-enabled communications are, in the present (2009-2010), under theoretical study only. There are numerous attempts to bring this technology to public use e.g. building public libraries of ontologies, but this field still resides only in the boundaries of the scientific community. To bring it to public use, tools should emerge, that would facilitate the semantic annotation and semantic description of entities, by any internet user, in various environments like web services, web pages, distributed software, reusable components etc. These tools should be easy to use by any internet user. They should incorporate automatic validation based on the recommendations and restrictions of the ontology engineering discipline. Only then, when the advantages of these technologies will overcome the difficulties of defining and maintaining the ontologies, will semantic-enabled communications be a part of common software and human activities.

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