A Cooperation System based on Ontologies

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Abstract: We present in this paper a cooperation system based on ontologies. To integrate heterogeneous knowledge, an hybrid ontology is designed. Besides, in order to reach cooperation between local ontologies, a computer-aided system is offered to assist experts to build mappings between entities of different ontologies. An approach is described to capture ontology evolution. We define a relevant proposal relating to the geotechnical domain involving different businesses and willing to cooperate.

1 INTRODUCTION

Knowledge management is a great challenge for industries. This involves the representation, capitalization, sharing and evolution of knowledge. The use of heterogeneous information sources distributed across multiple organizations makes these tasks more difficult.

Ontologies are a promised approach for knowledge representation in a formal way. In addition, they are used to ensure cooperation between heterogeneous information sources.

Since they appeared at the beginning of the 90's in the community of Knowledge Engineering, multiple definitions of ontologies are proposed. The well-known is defined by (Grüber, 1993): "Ontology is an explicit specification of a conceptualization". (Stüder et al., 1998) adds to this definition that ontology captures consensual knowledge shared by an experts' group. In fact, ontology includes concepts networks, relationships and axioms to represent and organize knowledge.

Various approaches established interoperability between knowledge contained in several information sources (Wache et al., 2001). We denote the approach with a single ontology, with multiple ontologies or with an hybrid ontology. In a single ontology approach, a global ontology is built to represent a shared vocabulary between all users derived from multiple information sources. In a multiple ontology approach, each information source is described in its own ontology. Moreover, in an hybrid approach a shared vocabulary is designed to allow cooperation between the ontologies. It can be a terminological resource, a data warehouse or a global ontology.

Different techniques based on ontologies are used to yield cooperation between several information sources and to allow semantic interoperability. In particular, ontology merging is the creation of a new ontology from several different ones. The resulted ontology contains knowledge of the initial ontologies. In the case of ontology integration, data from the first ontology is included in the second one. Ontology alignment is the process of determining mappings or relationships between entities of different ontologies.

In this paper, we propose a system based on ontologies to resolve problems involved in knowledge management and to allow cooperation between knowledge bases. Firstly, some related cooperation systems are highlighted. Then, the architecture of the offered system and the required hybrid ontology to represent domain knowledge are described. Afterward, the developed computer-aided system is proposed in order to yield cooperation in the process of mappings creation. Following this, the consequences of changes in ontology and some solutions to manage knowledge evolution are exhibited. We conclude with some perspectives.

2 RELATED WORKS

Many research projects have been proposed to achieve cooperation. We distinguish the works on database cooperation using ontologies and those on knowledge engineering. Their aims are (i) to design

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ontologies for knowledge representation and (ii) to allow cooperation between multiple ontologies. For the database cooperation, there are two types of systems: the first ones are automatic and the second ones require the experts contribution to resolve semantic conflicts between information sources.

OBSERVER (Ontology Based System Enhanced with Relationships for Vocabulary hEterogeneity Resolution) is a cooperation system for multiple information sources described in multiple ontologies (Mena et al.., 2000). Those are designed independently of others to represent terms in a sub domain capturing the information in a data repository. OBSERVER allows to create manually or semi automatically mappings between terms of the distributed ontologies. These mappings consist of synonym relations between terms in the different ontologies and are stored in a component called IRM (Interontology Relationship Management).

MOMIS (Mediator environment for Multiple Information Source) is a semi-automatic system for integrating structured and semi-structured data. It provides an environment to manage the users' requests (Beneventano et al., 2000). MOMIS is based on a mediator/ wrapper architecture: The wrapper translates each data source in a conceptual schema while the mediator provides the user with a Global Virtual View (GVV). It is described in an ontology representing the global classes and attributes, and the semantic relations between them. Users can send request to the GVV which asks the data sources.

OntoDawa (Ontology-based Data Warehouse) is an automatic system for autonomous and evolutive data sources (Nguyen Xuan et al., 2008). Each source contains its own local ontology and the semantic relations that articulate with the shared (global) ontology. This one is manually built by the experts while local ontologies are designed from the existing concepts in the global ontology. Therefore, the data integration is automatic thanks to the semantic relations between local ontologies extracted from the global ontology.

OWSCIS (Ontology and Web Services based Cooperation of Information Sources) is a cooperation system which uses two levels of ontology: The information source level (local) and the cooperation (global) level (Abrouk et al., 2008; Poulain, 2010). Information sources are semantically described using local ontologies, and a "reference ontology" describes the semantics of the domain. A semi-automatic method was developed to produce mappings between two ontologies (local and reference). In addition, a technique for cooperation querying was implemented. It is based on exploitation of the semantic contained in the ontologies and uses the different mappings created.

OMSys (Ontology-based Mediation System) is an automatic mediation system based on ontologies (Maiz et al., 2010). Its aim is to represent and to integrate heterogeneous data. Local ontologies describe the structure and the semantics of data sources. An ontology containing the global vocabulary is designed by merging the local ontologies. An algorithm based on techniques of Agglomerative Hierarchical Clustering (AHC) and the OWL inference mechanism is implemented. The AHC techniques classify the entities in the different ontologies in order to define the elements representing the global ontology. Users send queries which will be translated into the global language.

In the field of knowledge engineering, ontologies are used to support knowledge management and reasoning. In this context, several systems offer management of ontologies and cooperation between them by establishing semantic links between concepts and relations of two ontologies.

OntoMas (Ontology Matching Assistant) is a system designed to aid the alignment of heterogeneous ontologies (Huza et al., 2007). The project develops a knowledge base using the MAGDA architecture (Generic Mapping Discovery Architecture) which supports different alignment techniques. MAGDA classifies the alignment methods according to the used technique, the type of the obtained result and the existence of an algorithm to optimize the alignment. OntoMas provides assistance to choose the most relevant alignment technique in a given context.

TooCom (Tool to Operationalize an Ontology with the Conceptual Graph Model) is a tool dedicated to knowledge engineering (Fürst and Trichet, 2009). It proposes an approach to operationalize ontologies represented in OCGL (Conceptual Graph Ontology Language) in order to reason about domain ontologies and therefore to deduce semantic. It considers heavyweight ontology containing axioms to define the semantic of the domain. Thus, the semantic links between conceptual primitives (concepts, relations) are deduced from the axiomatic level of ontologies, and confirmed by calculating the "likelihood coefficient" of the alignments.

Three approaches are involved in these systems: An approach with a single ontology is used in MOMIS, an approach with multiple ontologies is used in OBSERVER, OntoMas and TooCom , and an approach with an hybrid ontology is used in OntoDawa, OWSCIS and OMSys. They offer both a significant autonomy to the local ontology and a shared vocabulary. However, to represent the whole domain semantic in a global ontology is difficult. The ontology is manually designed by experts, except in OMSys which proposes an automatic approach to design it but do not manage its evolution. We propose to develop a cooperation system based on an hybrid ontology. But, instead of describing the entire domain semantic at a global level, we represent only common concepts, properties and the relations which connect them. Experts can cooperate through the global ontology which offers a shared vocabulary and a set of mappings between the local ontologies. The system offers an assistance to guide experts to generate mappings between ontologies entities by proposing to compute similarity measures relatively to the ontologies characteristics. Contrary to the existing alignment systems (OntoMas, tooCom …), our system stores all the calculated similarities in order to reuse them. In addition, all the relations validated by the experts are also stored to maintain the consistency of the created mappings.

Among the presented projects, some study ontology evolution. In OntoDawa, several versions of the ontologies concepts can be stored and manipulated. The "current version" of the ontology represents the last version used for each concept. Moreover, the different versions of concepts and instances are stored in a database. In OWSICS, the addition or the deletion of a local ontology implies changes at the global ontology in order to recovers all the sub-domain of the local ontologies. In OMSys, only the data source evolution is captured by the mediator.

(Stojanovic, 2004) defines a process in six steps to manage the evolution. The first step identifies necessary changes to the ontologies. The second step identifies all the updates to the ontology that will be required. In order to maintain the consistency of the ontology, the third step provides all the derived changes involved by the required change. The fourth step ensures the consistency of the dependent objects (ontologies, instances, applications). The fifth step aims to inform the ontology users of the consequences of the changes, to implement the changes, and to store all the executed changes. Finally, the sixth step allows the users to authorize or refuse the changes with their effects.

(Djedidi and Aufaure, 2010) proposes a system called **Onto-Evoal** (Ontology Evolution-Evaluation) to manage ontology evolution and evaluation. The system is based on Change Management Pattern modeling. Based on these patterns and the semantic relations between them, the system integrates an automated process which manages change while maintaining the consistency of the modified ontology. In addition, OntoEvoal defines an ontology quality model to evaluate the ontology. This model is used to resolve inconsistencies by assessing the impact of the proposed resolutions on ontology quality. Thus, users can select the best solution.

(Jaziri et al., 2010) proposed an anticipatory approach and a tool called **Consistology** to manage ontology evolution and versioning. A taxonomy of types of changes includes all the changes which can occur in the ontology. The consistency of the ontology is anticipated by suggesting all the possible resolutions and their effects on the ontology according to a set of rules defined by the system. Finally, the validation of changes implies the creation of a new version of the ontology. Each version of the ontology is stored in a log and has a duration that ends at the application of a new change.

KAON (Karlsruhe Ontology) is a framework developed to manage ontologies (Stojanovic, 2004). It contains some modules for the creation, storage and application of ontologies. To manage the ontology evolution, KAON provides a log containing all the modifications that occur as well as the concepts and properties concerned. A model of changes describes some services that manage ontology evolution. A log model stores the executed changes, therefore allowing the possibility to go back at a previous version.

These systems cannot handle the management of hybrid ontology evolution. Our system has to consider the impacts of changes to local ontologies on the global ontology. A way of managing hybrid ontology evolution is described later.

3 ARCHITECTURE OF THE SYSTEM

To represent heterogeneous and distributed knowledge, we design an hybrid ontology on two levels: local and global. At a local level, business ontologies are built. Each one describes a sub-domain specificity respecting the point of view of an experts' group which practising a same business. At a global level an ontology representing a shared vocabulary allows to connect all the local ontologies. In order to yield cooperation between some business ontologies, we offer a computer-aided system to guide the experts in the process of mapping creation between concepts of local ontologies (Ziani et al., 2011b). Then, we propose an approach to support knowledge evolution.

We applied this work to the geotechnical domain (contract CETU n° 2005_4.69011). Therefore, we developed a knowledge capitalization system allowing cooperation between experts. The system is based on an hybrid ontology and manages its evolution. The cooperation is ensured thanks to the global ontology and a set of mappings. The architecture of this system is showed in the figure 1.

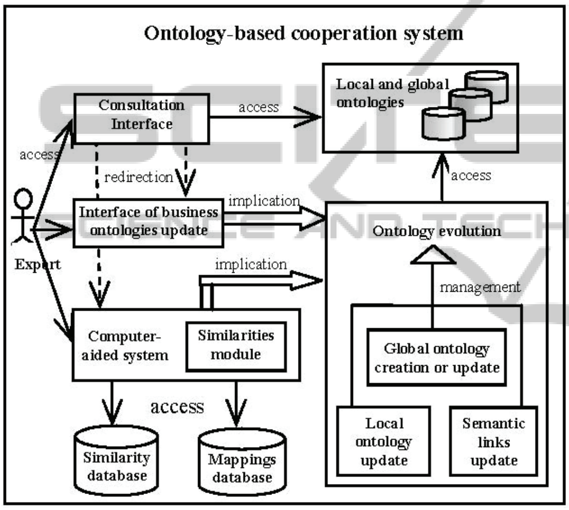

Figure 1: Architecture of the cooperation system based on ontologies.

The cooperation system contains:

- An interface of ontologies consultation: allows the experts to see all the ontologies and mappings existing between them.
- An interface of updating ontologies: to add/ modify/ rename or delete concepts/ properties or instances of its own ontology.
- A computer-aided system: to help experts in the process of mappings creation. It includes a similarities module which implements several similarity methods and measures.
- A mapping database: stores all the discovered mappings.
- A similarity database: stores all the calculated similarities.
- And a module for ontology evolution: includes three modules. The first one implements a merging to create or update a global ontology. The second one supports the local ontologies update and the last one manages the semantic relations update.

These elements, the locals and the global ontologies interact with experts in order to create mappings between concepts of two ontologies and to support the evolution of the hybrid ontology.

4 HYBRID ONTOLOGY REPRESENTATION

To represent knowledge from heterogeneous and distributed knowledge bases, we designed an hybrid ontology. It consists of local ontologies describing concepts, properties and instances used by experts in a given business and a global ontology containing only concepts and properties shared by all. Each local ontology is manually built by a group of experts who share the same point of view, while a global ontology is automatically designed by the system. A merging algorithm was developed to create it (Ziani, 2011a).

The figure 2 shows a part of a class diagram which describes the hybrid ontology written in OWL. The diagram represents some RDF resources (Ressource Description Framework) identified by a URI (Uniform Resource Identifier) and an object 'synonym' extracted from a database.

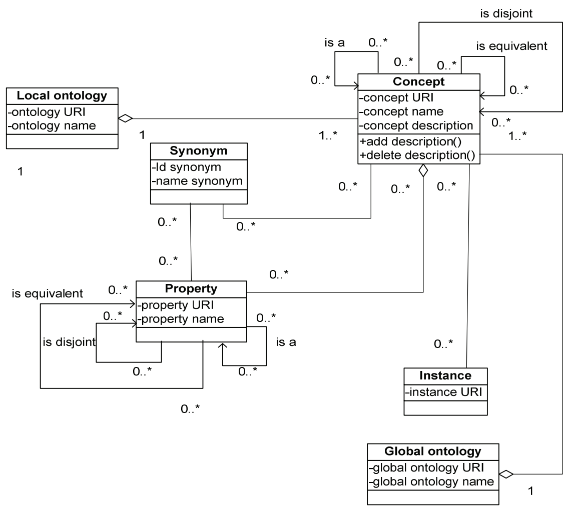

Figure 2: Class diagram describing a part of the hybrid ontology.

The figure 2 describes a simplified UML diagram:

- Global ontology: identified by a URI and composed by a set of concepts and the conceptual relations "is a" which connect the concepts.

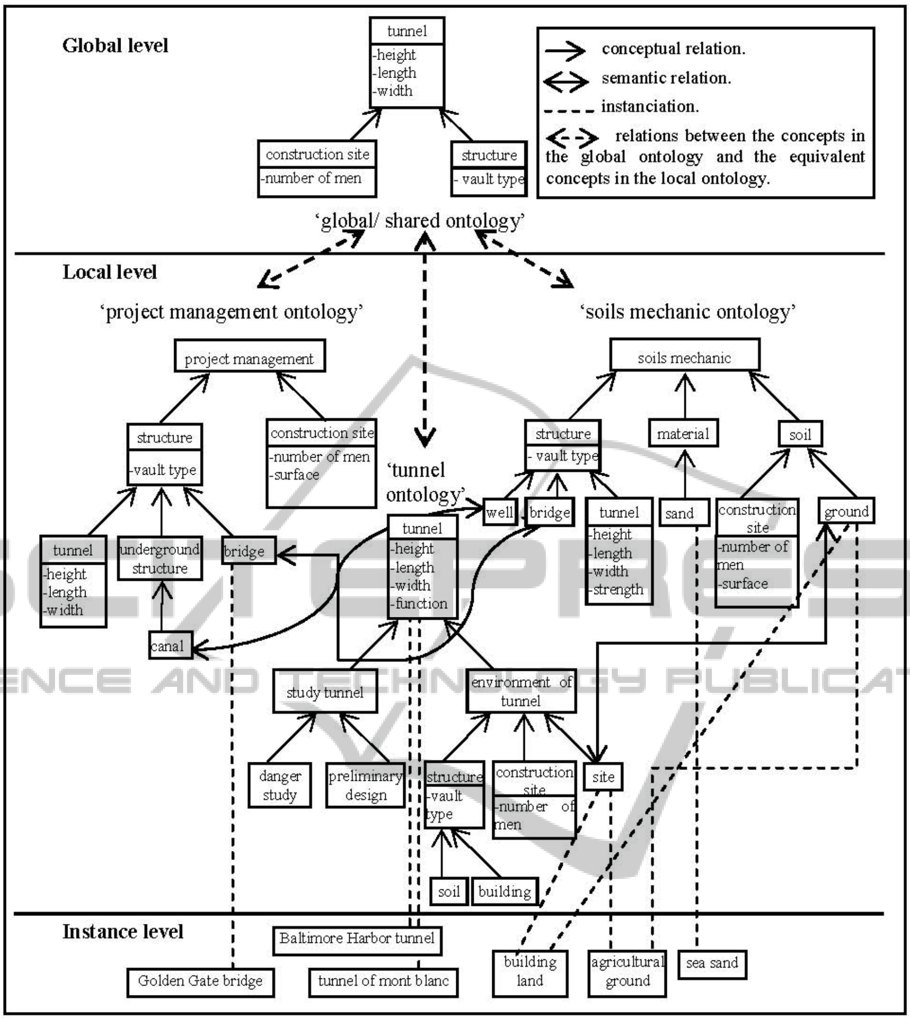

Figure 3: Part of the hybrid ontology representing the geotechnic domain.

- Local ontology: identified by a URI and includes concepts, conceptual relations, semantic relations ("is equivalent", "is disjoint") and instances.
- Concept: identified by a URI and defined by a syntagm. In addition, each concept may have a description.
- Property: identified by a URI and described by a syntagm.
- Synonym: each one has a unique identifier and consists of a syntagm.
- Instances: identified by a URI and represents a concept instance. Each concept has zero, one or many instances. An instance concerns one or many concepts.

Each concept contains either zero, or one or several properties and instances. Each property and each instance concern either one or several concepts. Concepts or properties may have synonyms and each synonym concerns 0..N concepts or properties.

The class diagram is simplified because we have also the class of relation concept which allows to represent richer semantic relations. An example of an hybrid ontology that we developed in the RAMCESH project is given in the figure 3.

5 ONTOLOGY ALIGNMENT

Our system allows the cooperation between experts through the ontologies alignment. In particular, it offers a guide to an expert in the process of the creation of mappings between concepts of different ontologies. This process is presented in the figure 4.

When an expert wants to create a mapping between its ontology and another one, he sends a request through the 'search interface of mappings'.

This one interrogates the hybrid ontology to find the names of the different local ontologies. Thus the expert selects the name of the initial ontology and those of the research ontology. The first one corresponds to its business and the second one is the ontology he wills to cooperate. The selected ontologies and the global are imported. This later is required to disambiguate the meaning of ontological entities in different ontologies. All the concepts of the initial ontology are proposed via the Interface and the expert selects one of the returned concepts. The objective is to discover the concepts of the research ontology to align with the concept of the initial ontology.

Once all the parameters (initial concept, initial ontology and research ontology) are submitted via the 'search interface of mappings', a request of researching similarities is sent to the 'assistance module'. This later forwards the query to the 'mappings database' where are stored all the similarities. If synonyms of the initial concept exist in the 'similarities database', they are returned and proposed to the expert.

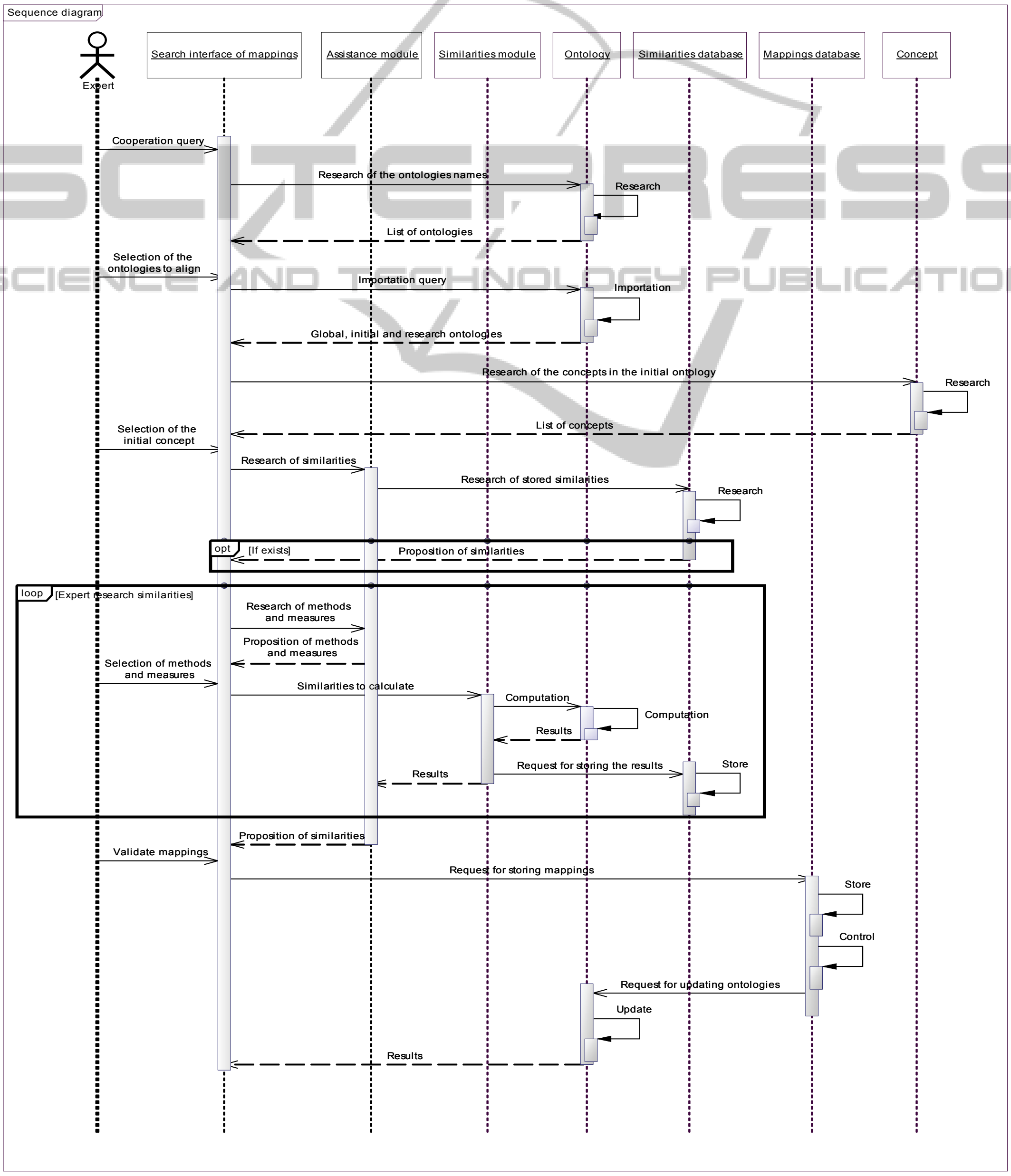

Figure 4: Sequence diagram representing the alignment process.

While the expert researches similarities, the 'assistance module' proposes to compute similarities measures using the 'similarities module' where all the methods and measures of similarities are implemented. The scheduling of these proposed measures depends on the previous returned results and the characteristics of the ontologies to align (ontology granularity, number of concept properties and instances).

Each found similarity is stored in the 'similarities database' and proposed to the experts for validation from the 'search interface of mappings'. Then, the expert can validate the found similarities. The semantic links proposed and the expert names are stored in the 'mappings database'. Finally, a control in the 'mappings database' allows to verify the consistency of the generated mappings and therefore requests to update the ontologies (creation, modification, deletion).

Through this process, the system allows to store all the calculated similarities in order to reuse them and the generated mappings to verify their consistencies. This interactive system aids to select the best relevant similarity measures and is based on a computer-aided algorithm to research similar concepts (Ziani et al., 2011b).

6 HYBRID ONTOLOGY EVOLUTION

The evolution of the knowledge domain and the use of the ontologies for different tasks induce changes in the local ontologies describing the businesses of the domain. These evolutions induce changes in the global ontology (updated concepts and the properties after modifications) and in the mappings created during the operations of alignment.

At each change, the system has to send notifications to inform the experts about the consequences of an asked change. Before taking in account, the expert has to validate the modifications involved. Furthermore, the system has to preserve all the versions of the ontology evolution.

6.1 Management of Ontology Evolution

There are three types of changes: Elementary, composed or complex. The elementary change modifies only one entity of the ontology (add, modify or delete). The composed change creates modifications in the neighborhood of the ontology, and the complex changes involving elementary and composed changes (Stojanovic, 2004).

The elementary changes are directly performed by the experts. Composed and complex changes require verification into the locals and global ontology. They mainly concern, the addition or deletion of business ontology and the addition of concepts sharing by all the experts. The solutions proposed for the verification of the consistency of a global ontology are:

– **For an Addition of Business Ontology.** The addition of a new ontology involves its integration in the global ontology according to the approach of designing an hybrid ontology (Ziani et al., 2011a). It consists to verify if all the concepts and properties of the global ontology exists in the added ontology. In the contrary, the concept or property is deleted in the global ontology.

– **For a Deletion of Business Ontology / Addition of the not Leaf Concepts.** The deletion of a business ontology and the addition of not leaf concepts into a business ontology can involving the modification of the global ontology if there are new concepts common to all the business ontologies. These concepts must be integrated into the global ontology and the relations which will connect them to the other concepts in the global ontology are deduced from the links which connect this one to the other concepts in the "target" ontology (the business ontology which was identified during the creation of the global ontology). The conceptual graph obtained is verified with an algorithm which allows to delete the conceptual relations providing cycle into the global ontology. This relation is only stored in the local ontologies (Ziani et al., 2011a).

6.2 Management of Mapping Evolution

The system automatically updates the mappings validated by the experts.

When an expert suggests to add a semantic link between two concepts, the relation and the expert name are stored in the mapping database. Then, the system verifies if another relation between the concerned concepts exists in the database. If there is no relation, the system generates a mapping between these concepts. On the contrary, if there are one or several semantic relations between these concepts, the consistence of the ontology is verified and the existing mapping can be deleted or modified by the adding of the new. There are two possibilities: Either the same alignment exists, in this case there is no modification to be brought to the ontologies, or there is a contradictory alignment: In this case, we cannot create this latter. The alignment previously created is deleted. It can be recreated only by a third expert who confirms one of the existing solutions or by an expert who modifies the alignment which he has previously proposed in the mapping database.

The expert can modify a relation which he has created in the similarity database. This modification can involve the updating or the deletion of the generated mappings.

The expert can also delete a relation which he has created in the similarity database. As previously, this operation can modify or delete the generated mapping between the concerned concepts.

7 CONCLUSIONS

The cooperation system we developed, allows to represent heterogeneous and distributed knowledge through an hybrid ontology, and to reach cooperation between experts with different points of view. In addition, it manages the hybrid ontology evolution. This system is generic and can be applied to all the domains with several identified sub-domains. In particular, we applied this work to the geotechnical domain.

Currently, the system of the geotechnical knowledge management is partially implemented (the implemented part concerns the hybrid ontology design and the ontology alignment).

Therefore, our future work is to enable the system to automatically support the hybrid ontology evolution and to manage the different versions of the hybrid ontology. Another perspective of this work is to estimate all the mappings stored in the similarity database in order to deduce other semantic relations. Finally, it would be interesting to study the scalability of the hybrid ontology and the alignments between concepts.

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