The Use of Knowledge Management in the Management of Tunnels and Tunnel Projects.

N.R. Faure[1], R.M. Faure[2], G. Hemond[1]

[1] Solem France SA, 74166, ABC 1, International Business Park, Archamps, France
[2] Centre d'Etude des tunnels, 25 Avenue Mitterrand, 69500 Bron, France

ABSTRACT

We present, in this paper, the use of tunnel domain ontology and a new knowledge component called 'granule of knowledge' that allows the definition of new approach for tunnel design. The first part of the paper describes ontology, granule of knowledge and network implementation, the second part three applications among several that show the powerful capability of the approach.
Finally, we develop the innovative impact of these applications that can change the usual procedures of engineering and also allows better knowledge transfer between generations.

1.INTRODUCTION

1.1.Context of this work

The on coming techniques of knowledge management (KM) can be used for a better management of tunnels and for better tunnel designs. CETu (French National Center for Tunnels) and SOLEM Company have developed a new kind of storage of information that can give a very high level of potentialities. We demonstrate these potentialities through the description of applications under development in Solem and CETu. This new storage can be done with the help of experts of the domain of undergrounds works, without the two constraints that are: experts are never free, except for few minutes and experts are not able to make long research, they react immediately or never. So we imagine an on line system that allows the use of experts friendly for the storage of all knowledge about undergrounds works. This system is called RAMCESH.

In a first part of this paper we present the results of the RAMCESH project giving us a new comprehensive approach of KM. (RAMCESH is the acronym of 'Recueil Assisté et Maniement des Connaissances pour les Espaces Souterrains Habités', that means 'Assisted collect and use of knowledge for underground living spaces'). The development of RAMCESH is based on ontology and granule and the use of the system depends of context and collaborative tools. These four topics are developed in this first part.

- Ontology of underground works: what is an ontology and for what use?
- The 'granule' of knowledge: a powerful representation of knowledge.
- The context of underground works: how to describe it in a computer?
- Collaborative tools for a simple but efficient use of the domain experts.

As we said that all the knowledge of undergrounds works is stored, it is obviously for use. In the second part of this paper we describe three applications using ontology of tunnel and the knowledge base.

- Knowledge management and research.
- Standards verification for the design of a tunnel work.
- Best tender choice in upgrading a tunnel.

1.2. A challenge with computer technology

One of the main difficulties when developing a computer system meant to be effectively used in an organization is to adapt the existing technology to the system, or reversely. We try so, to define a tool that is no dedicated to a technology, no dedicated to a language, and with a very easy maintenance made by the geotechnicians themselves.

The first objective of the RAMCESH project is thus more concept-oriented than computer-oriented; in other words, it is before all a study on knowledge representation, and an interrogation on how knowledge can be represented in classical and existing softwares, be them databases or web-oriented languages (XML and developments, notably).

The prototype as it was developed is supported by a database and a simple language, each being free and easily downloadable, and can effectively be installed on other kinds of systems – as long as they allow to stock data and request it.

Moreover, maintenance of the system must be simple in order to prevent the classical technical barrier, which prevents users to effectively use every possibility of the knowledge tool. Adding to the rather informal side of the system, RAMCESH is no "blackbox", i.e. does not prevent users to access what is inside, data and functionalities alike (this does not mean there is no access control, however).

1.3. In fact a very long approach

The coming of these ideas is due to a long thought about K.M. Since 1985 similar research was done about expert systems applied to ground works, mainly slopes. (Faure et al.,1992), (Mascarelli et al, 1992), (Mascarelli, 1994). Even if some disappointment occurred (Magnan, 1992), from expert system we went to databases through the net. (Faure, 1999). All these contributions are the background of the RAMCESH project.

2. PART I : KNOWLEDGE MANAGEMENT

2.1.Knowledge static approach and the world description

2.1.1. Ontology

Ontology is the philosophical enterprise which consists essentially in classifying every element of the universe. This is quite a enormous enterprise and since Aristotle, which initiated it, philosophers are not even near to fulfil the objective – mainly because various systems of categorization have been proposed, each one not entirely satisfactory.

Since the end of the 20th century, ontology[1] is also a computer science matter. (Neches et al., 1991) described a way to represent useful vocabulary for a domain[2] which is referred to as ontology.
Ontologies are since a very busy research domain, and evolved from a terminological tool to a knowledge tool : each word representing a concept, the structure of a domain vocabulary is tightly linked to domain knowledge (Guarino, 1998).
As early as 1993, ontologies definition had evolved to the famous (but still hotly debated) :

“Ontology is the specification of a conceptualization” (Gruber, 1993)

Which means that an ontology represents explicitly the way that domain knowledge is structured. This representation is often built with concepts and relations that link concepts together.
It implies four things, among others :

- an ontology is tributary of a point of view, as a conceptualization refers to a person, or group of persons

[1] Ontology is philosophy with an upper-case letter, and computer science when plural or with a lower-case letter.
[2] Domain refers to any coherent area of human activity (which is, by and large, any professional activity).

- an ontology is simplified with regards to reality, for it is intended for a specific use. Some irrelevant links between concepts are to be left over
- an ontology can bring in some linguistic problems : concepts are represented as words, and they are rather blurry and elusive in their uses
- furthermore, an ontology alone is not a knowledge-based system : ontologies feature one form of knowledge, i.e. declarative knowledge, defined as knowledge based on explicit rules and definitions. This is often insufficient to usefully model domain knowledge

So, why build an ontology?

Ontology is a useful tool for communication between systems, persons and organizations, as it is a synthetic and rather exhaustive way for expressing a point of view about a specific domain and build common references (Corcho et al., 2002).

For instance, ontologies are mainly used for semantic enrichment of requests, i.e. enlarging the scope of a request (in a search engine, for example) to all potentially pertinent answers (from rock to granite, for example, or from granite to mica), without generating too much answers. So, ontologies are used for Semantic Web, Multi-Agent Systems, Problem-Solving Methods libraries, and so on…
Other solutions could be chosen (Minsky, 1974), obviously, but ontologies seem to be an ideal solution for building an underground works knowledge-based system.

2.1.2. Specificities of underground works ontologies

Underground work ontology is a huge task, as this domain is in fact at the cross of various disciplines, domains in their own right: geology, soil mechanics, physics, chemistry, etc…

This fact alone brings a lot of terminologies and definitions of same (or very neighbouring) concepts ; categorization is thus difficult at best – furthermore if this categorization has to be shared between specialists from various disciplines. As example mining geology doesn't use exactly the same words than tunnelling geology, or the 'soil' is not the same concept for a geologist, a podologist or a geotechnician.

In fact, properties of a concept are not equally stressed in a domain or another – size of a particle will be less a valuable consideration for a chemist than for a geologist. More, name of a specific soil or rock formation are often regionalisms, and do not always have the same name in other places. What is named after a specific soil formation (i.e. a geological era) can thus suffer of this regionalism.
These are cases of synonymy or close, but cases of metonymy and, more generically, cases of specific use of vocabulary are also caused by this heterogeneous environment – heterogeneity brought from the very public and the very object of underground works.

In this context, it is conceivable that a simple terminological reference is quite an utopia, for it comes to normalisation: a long-run endeavour, which should mobilize the whole underground works community; and that is far beyond the scope of this project.
Another crucial element in considering an underground works ontology is who will use it, and how. Knowledge engineers usually build and maintain ontologies, but it means that experts of the domain are out of the building and maintaining process – unless time-consuming and imprecise expert interviews are done. However, in the case of shared knowledge, this appears to us as a paradoxical choice. So, the builders have to be the knowledge sharing community: the domain experts.

It implies that our underground works ontology has to comply even more with the natural language contingencies described above, and that it generates few constraints to use. It implies, too, that it must use a network that can enable expert to constitute this ontology wherever they are – namely, the Internet.
With so many potential users and so much complexity to handle, we chose not to engage in a rigid conceptual formalization – as in such an environment, the declarative knowledge[3] usually featured in ontologies is not so declarative.

[3] "Declarative knowledge" is borrowed from cognitive psychology, and defines any form of knowledge which is represented by a rule, a law or a (mostly) univocal definition of some sort

For representing concepts, we chose to use natural language and not formal definitions, nor the set of properties which define a concept in the classical point of view. Concepts, as categories, are classically defined by the set of common properties of all its instances. As concepts are usually not considered using all their instances (intentionally), it is rather considered that any object which features a representative number of said properties belongs to said category.

It is proved that the real, cognitive, approach differs from this classical point of view : most notably, the works of Ludwig Wittgenstein, at the beginning of the 20th century, and later research in cognitive science showed that concepts are a more complex affair[4].

The RAMCESH project so supports a semi-formal ontology, as it features natural language concepts definitions, for sake of use and conceptualization (Uschold & Gruninger, 1996).

2.1.3. RAMCESH 1 : the way for building tunnel ontology

Ontology is constituted from various hierarchies (taxonomies), each being defined by a specific relation. The simplest way to build ontology is thus to build first the various hierarchies needed then to join them.

It brings first the question of which hierarchies – which relations – are needed in underground works ontology.

Obviously, "is-a" relation (subsumption or specialization) is a must-have for any ontology, underground works being no exception : if one isn't able to go from a generic concept (say, rock) to a more specific concept (say, granite), or the reverse, then most of possible inferences will be lost for the domain.

The second of possible relations is less frequent, as it is the aggregation (or composition) relation, which allows to link granite and mica for example. Aggregation is quite an ambivalent relation, for it can include partition (a wheel is part of a car, for example), or composition in a chemical point of view (hydrogen is part of water). Aggregation in the RAMCESH ontology is rather of the first type, as geotechnical analysis requires more often aggregation from parts than from molecular elements. Furthermore, it would probably mean that our primitive elements – ontological concepts – are to be defined from a molecular point of view.

It is possible to imagine more relations and more hierarchies to build the ontology, but, as complexity increase for the overall ontology with each hierarchy, it is necessary to restrain the number of ontological relations – subsumption and aggregation seem to be sufficient.

In order to facilitate the use of the ontology, each concept is labelled by a set of words – accordingly to specific cases of use. Words of this set can be the denomination for another concept ; this quite comes to a third conceptual relation, of synonymy. However, as it functions differently, it can't really be regarded as a fully-developed ontological relation.

The ontological relations are so arbitrarily chosen; concepts are not. Knowledge comes in RAMCESH from the domain documents: review papers, official papers, and so on… There are three main reasons for this choice:

- Usually, documental knowledge is already reviewed and do not ask for supplementary reviewing
- Documental knowledge is more readily available than specialists (or, more accurately, specialists' time)
- Documental knowledge can be processed automatically (or at least semi-automatically)

The first step to build the RAMCESH ontology is to collect a corpus of texts – the way of selecting these is relevant only to the community concerned by the ontology. These texts are then analyzed by a natural language analyzer (RAMCESH currently uses the Likes[5] engine, but another one could be relevant), which selects significant nouns (based on their number of occurrences) in the texts. This process is known, in the RAMCESH project, as "text crunching".

[4] Wittgenstein used the « game » concept to show that there is such concepts as they are intuitively understood by everyone but lacks a sufficient set of common properties to be extensionally defined. The later logicians introduced the prototype to explain how a concept is built.

[5] Graciously lent by the ENSAIS-INSA based in Strasbourg, France

These nouns are then presented to selected specialists, who classify them in the various hierarchies of concepts (semantic analysis of a text is yet too uncertain to allow a full automatism in this process). Nouns are defined as univocally as possible, and then synonyms are given to each.

The hierarchies are then merged in ontology. Strictly speaking, what is obtained is extensive pragmatic lightweight semi-formal domain ontology[6].

As such, ontology is quite useless. It can be used as a knowledge repository, as a database, but it constitutes only the first step to the knowledge system completion.

2.1.4. The ontology now

First, we choose general texts as handbook about tunnel (CETu, 1999), syllabus, rules as Eurocode 7 and some important papers. After 'crunching', with the help of MindManager, we built trees of words in A3 sheet format as it is easy to print. This presentation is a very powerful tool for discussions between experts and from these discussions we attempt to a good quality of our ontology. The main constraints when building are the uniqueness of each syntagm (word or set of words) and the subsumption and aggregation links that we can only use. The following figure shows the first three levels of the ontology. Each "leaf" of the tree is a complete map that can use until 300 words. The total number of syntagms in this ontology is more than 5000.

This ontology is now displayed through the net (with password) and experts can improve it in a collaborative way.

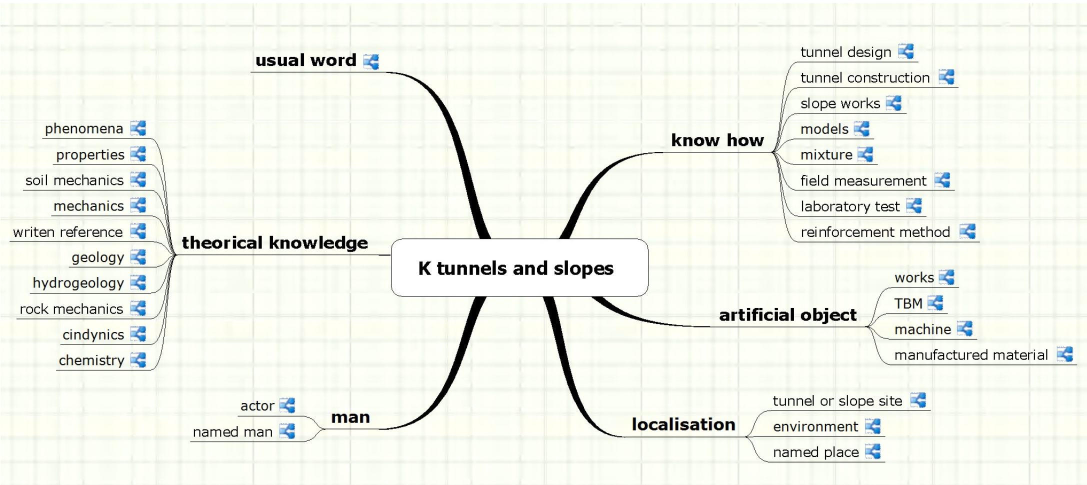

Figure 1. first levels of ontology

2.2. Knowledge dynamic approach and the granule of knowledge

2.2.1. The settlements of granule theory

The second part of the RAMCESH system is the set of knowledge granules (Faure, 2004).

As seen in the first part of this paper, the ontology features what is called declarative knowledge, that is, any kind of explicit, defined, knowledge. According to cognitive psychology, there is two other kinds of knowledge: procedural (know-how, any knowledge that allows to perform a task) and conditional knowledge (knowledge depending on environmental, contextual, conditions to be valid).
Of course, there is no rigid boundaries between those three kinds of knowledge (and it would be more precise to speak about forms of knowledge than kinds of knowledge), but in the scope of this paper, let's say that granules of knowledge represent procedural and, mostly, conditional geotechnical knowledge[7].

In order for those granules to be useful, they have to be computer-handled, if we can say, but in a way that users (who are, as mentioned above, geotechnical specialists, not computer- or knowledge-

[6] According to some of the numerous characterizations ontologies can have

[7] To be rigorous, it is a declarative form of conditional knowledge

science specialists) can handle them too. Granule formalism has to be light (which implies some measure of semantic liberty) but effective (which implies not too much semantic liberty) (Clark & Porter, 1997 ; Clark et al., 2000 ; Clark et al., 2001).

Knowledge granules are, thus, a light formalism that represents geotechnical knowledge in a computable way (which means, that allows inferences and orderings).

As with the ontology, granules involve a set of relations and concepts. The concepts featured in the granules are strictly the same that are featured in the ontology.

The relations, however, are not the same than those which are featured in the ontology : they are more precise, less universal, more contextual relations, such as relative positions, relative speeds, characterizations (colour, aspect, etc...), and even a few process-oriented relations (time relations mostly). These relations, as they are used to describe job-oriented situations, are called in the RAMCESH system "professional relations".

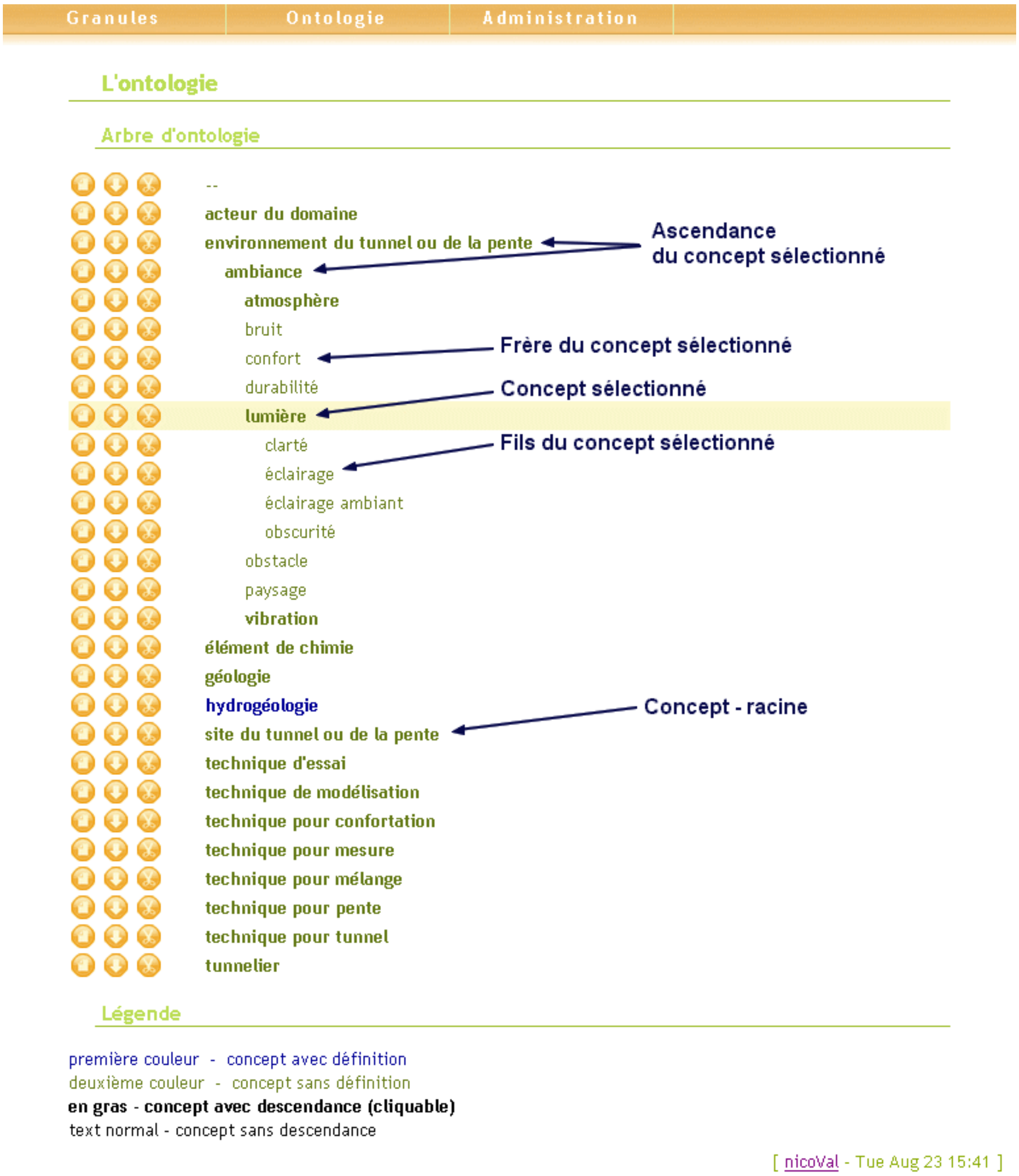

Figure 2. The user-friendly interface for working with ontology

Those relations (circa fifty identified as of the publication of this paper), unites "thematic" concepts and "predicative" concepts. Theme and predicate stands for, respectively, "what is spoken of" and "what is said about the theme". It is a structure borrowed from natural language, and is relatively intuitive. A theme is mandatory and features only one concept. Predicate can be empty, but can feature as many concepts as needed, each linked to the theme with a professional relation.

A couple theme-predicate constitute a "sentence". Each sentence is united to the other via a Boolean relation. Inside a granule, there is two groups of sentences: premises and conclusions. Premises are context; conclusions are implications from this context. They are linked with another, (as yet nondescript), relation: the relation of implication (Blair et al., 1992).

What is known of the context and subsequent implications is borrowed from texts (the same that were used to constitute the ontology), and manually treated in the granule syntax (a automation of the granule creation process is currently studied).

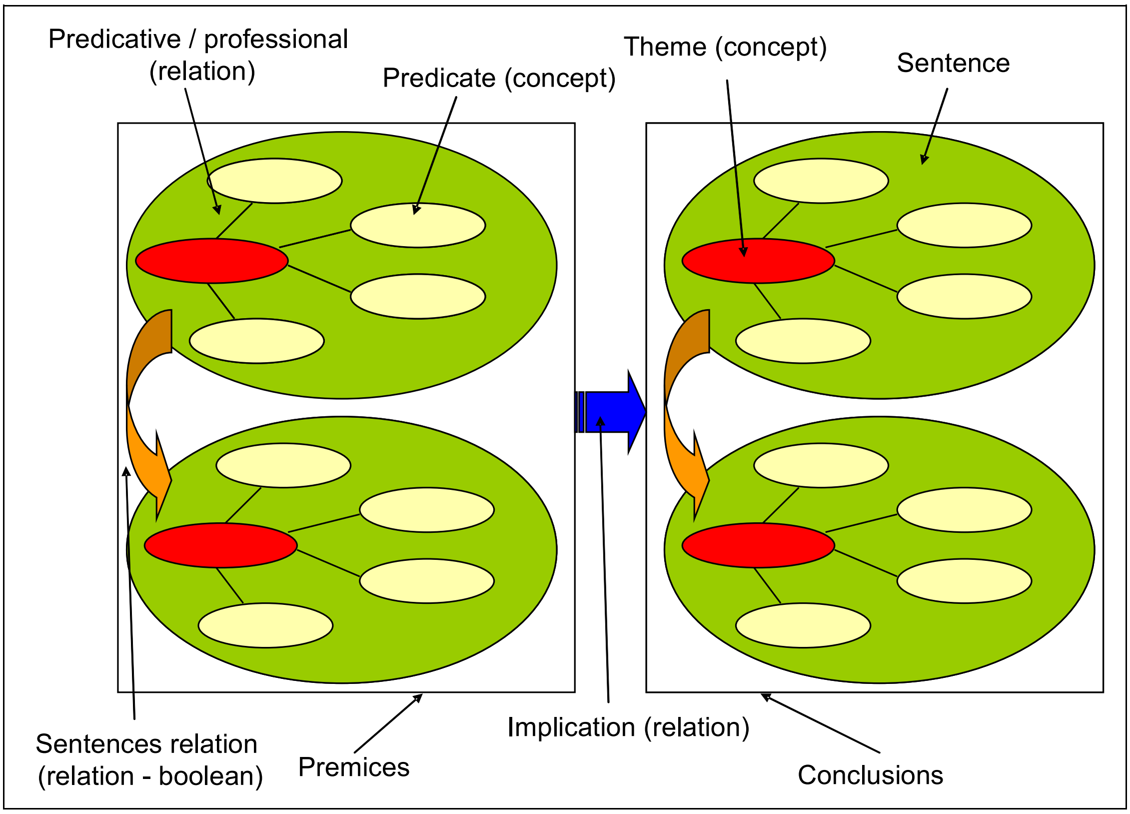

Figure 3. Generic granule

A granule features more elements: a universe and a model, respectively summary of every instance conveyed by means of a concept in a granule, and equivalences between those instances.

Universe and model are used for quantification and determination, as a concept can cover many elements, or two occurrences of the same concept can cover the same element. Quantification and determination, signification of a granule apart, are of the utmost importance for granules aggregation. This, along with the semi-formal syntax, ensures the "computability" of the granule.

2.2.2. Granules and specificities of undergrounds works knowledge

Underground works knowledge has much specificity regarding knowledge management and representation.

First, all element in underground works are not known, they are approximated as precisely as possible with test borings and geological considerations**;** this is in opposition with the industrial environments, where every element is known at each stage of the process.

Second, every characteristic of any identified element is rarely known, often estimated; which justifies a conceptual approach different than usual, but also a contextual approach.

In this way, geotechnics and underground works are more empirical than most of any other sciences, and thus has representational needs based more on transfer process (from expert observations) than on model process (based on the representation of every interaction in the environment). In other words, emphasis must be put on environmental conditions that imply some characteristics not directly observable – but this deductive process is, mostly, an expert process.

Which is why the knowledge granule is divided into premises and conclusions, context and implication – it is the most natural way to evaluate a situation from a geotechnical point of view, and the most frequent way situations are presented in technical papers. In fact, granule is an extended production rule, which was the base of expert systems.

Another point is that from unknown elements and characteristics are born fuzziness; an element in a situation can be identified generically more than specifically – the approximation mentioned above. Such approximation is not handled in the granule specifically, but rather in the combination of both granules and ontology, with what is in fact request enrichment, but is called "semantic shift".

2.2.3. The use of granules

Semantic shift is simply the conceptual variation inside a granule – of course, this is user-controlled variation.

A concept in a granule can be changed for another, next concept in the ontology, along whichever hierarchy (i.e. according to a relation or another). In this way, it is possible to retrieve and evaluate every semantically neighbouring granule, which is every granule with a good probability of pertinence in a described situation.

Therefore, the system allows users to express some conditions and retrieve from the knowledge base every bit of knowledge corresponding to this situation. It is then possible to imagine various requests and constraints to put these results to good use; the first one (simply said) being the aggregation of granules from a defined starting point, which allows a whole underground works project (or, at least, part of, depending on contextual sequencialization) to be represented with granules. This kind of system use is really computer-assisted development.

It must be stressed here, however, that at every point of the process the user (domain expert, i.e. geotechnician) has the final word on what is valid and what is not; RAMCESH is a knowledge-based system, and inferences apart, cannot pretend to create new knowledge – it is thus restrained to what knowledge is stocked in the knowledge base.

That is for this very reason that it is an online project, as it should allow knowledge to be inscribed in the system from a vast community.

2.2.4. What does a granule contain?

Name of the granule

Paper or document references (several references are possible if the granule is found in several documents)

The text portion

All the words of ontology associated to the granule (semantic shift)

The writer name and the last date of modification

The premises and conclusions (frame of words)

The universe (if necessary)

The model (if necessary)

2.2.5. Practice of a granule writer

As mentioned above, written documents (the same that for ontology) of any type are the starting points for enlarging the database of granules. Reading carefully the text the reader detects any sentence in which the general shape 'if…..then…' can be identified. This sentence is a granule candidate and is sent to the user-friendly interface, which using ontology enlarges the vocabulary and it remains to the writer only to define the frame of the granule clicking on the syntagms with the mouse. If an other granule seems to the RAMCESH 2 code, to be very close to the new one, some repetitions exists often in papers, the writer can modify or skip it, assuming the uniqueness of knowledge in the data-base. Last, the writer defines universe and model.

3. PART 2 : APPLICATIONS

3.1 Knowledge research

The first and most obvious use of RAMCESH system is that of knowledge research and retrieval, as partially described above. From a real situation, the user enters in the system what he perceives – or already knows. The system then identifies conceptual correlations between stocked granules and concepts so typed in. It brings to the users the granules most closely related to the partial description; then semantic shift is applied and other granules are showed.

Knowledge (in granule form) can be also be looked for in another way, via document references: author, date, etc… Sorting can also be executed along these lines, allowing easy access to pertinent knowledge if needed after the first request.

3.2 CONFEC 7

Soon, Europe will have to check the conformity of all civil engineering works with Eurocodes, and for geotechnics the adapted Eurocode is Eurocode 7. Our application, called CONFEC 7, aims to check if a design is in full agreement with Eurocode 7. It is a standard verification for the design of a tunnel made by an administration. In this application, the main challenge is to put the usual design of a tunnel, in a format suitable for comparisons with the requirements of Eurocode 7 as to feed the display of all the points not in agreement with the rules (Baget et al., 1999). The formalism of the granule helps us. Using the ontology, a computer module recognizes all the domain syntagms in the text explaining the design, and with the help of an engineer, set all granules that describe the design. Inside the granule, the associated 'model' gives the value or the range of value that the parameter must satisfied.

When the design is a set of granules, the computer compares it to the set of granules issued from the rules of Eurocode 7. The comparison is easy, searching if premises of granules belonging to one set have conclusion in the other set. The result of this comparison is a list of warnings for all non satisfied premises that the engineer must take in account.

Unsatisfied rules of Eurocode are so detected and the design must be corrected. Following the same approach inconsistency inside the design is also detected.

For administration CONFEC7 is a useful help, but any designer can, in the same way, check his design for a better quality design.

3.3. Towards TUNNEL EXPERT

This application will be a generalised approach following the works developed in the European Community project UPTUN (Khoury, 2005). In UPTUN, an important analysis is done about safety measures and safety improvement. We can extend improvement also for civil works in the upgrading design. The use of catalogues, for choosing easily any feature, and the use of formularies for feeding the linked codes give to the engineer and useful help for his design. These codes are compulsory for any determination of parameter needed in a granule. The links with codes (all are re-written in PHP language) are quite easy in this environment. As it is easy to change any quantity or any feature; TUNNEL-EXPERT leads to the best tender choice in upgrading a tunnel.

For this general use, we have to store all the world of tunnel, and the evolving ontology is really appreciated, the granules defining the use (or non use) of features have to be determined from catalogues, recommendations or from heuristics, that leads to a huge data-base, and will give us job for some time.

3.4. Others

Others application can be defined and each will be easier to build as ontology increase and granule writing is more masterised.

We think, as example, to crisis management in a tunnel. This application shall be a help for the managers of a tunnel when occurs an incident. All previous thinking can be display in good order following the situation, displaying to the operator the best choice for preventive actions.

And the granule structure may be useful for case based reasoning, comparing quickly stored cases.

4. CONCLUSION

4.1 Innovative impacts

We think that we have now reached a key point, allowing experts to store and use all kind of knowledge. The versatile properties of the granule are not fully discovered, but, until now, all knowledge can be described with the granule schema. The possibility of enlarging the ontology during the writing of a granule is appreciated, and certainly will be the major way for its completion.

The computer approach, all is on the net, is a simple answer to the challenge of using small bits of time experts and also a simple way of using RAMCESH without any learning.

We can't give, today, a measure of the innovative impact in the profession, as only few small groups of experts are allowed to use RAMCESH, but for all of them, it is really a new and powerful approach, giving them new ideas regarding tunnel design and knowledge transmission.

4.2 The future works

On the base of ontology and a database of granules, we shall fully develop the described applications, enlarging ontology and database. But other applications have to be defined, certainly with new cooperative teams. With WG 18 (teaching) of ITA/AITES, teaching ways will be explored. We expect a public release of the project by one year and a half (circa 2007).

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