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CONCEPTUAL MAPS BASED SYSTEM TO CAPTURE KNOWLEDGE IN DISTRIBUTED COLLABORATIVE R&D PROJECTS

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ABSTRACT
Nowadays, worldwide economy and competition often lead companies to setup temporary alliances with other companies in order to respond to business opportunities. They often join their strength by gathering their research and development (R&D) services into a virtual enterprise (VE) in order to develop engineering design projects in a more efficient way. The work presented in this paper has been developed in the context of the European network of excellence Virtual Research Lab for a Knowledge Community in Production (VRL-KCiP). This network gathers 24 teams of expert researchers in the mechanical production field over 15 European countries. The works, which are carried out in the VRL-KCiP and in a VE are similar: engineering projects are lead in a collaborative and distributed way. The assignments of such virtual organizations (VO) are quite the same and consist mainly in producing collectively new knowledge in order to solve problems. Thus, managing knowledge is of major importance in such a context, due to the high value of knowledge today. In this paper, a system for conceptual knowledge management in virtual organizations is drafted and positioned towards an existing system named n-dim.

Keywords: knowledge management, collaborative R&D, conceptual map, ontology

1 INTRODUCTION

Because of globalization and competitiveness, companies more and more often join their strength by gathering their R&D services into a virtual enterprise (VE) in order to develop engineering design projects in a more efficient way. This kind of distributed structure can be found in other contexts such as research with virtual labs. The generalization of this concept of distributed structures leads us to a more general term: virtual organizations (VO).

Those kinds of collaborative networks are emerging thanks to the development of new Internet-supported collaborative tools. Although there exist many forms of those organizations, they have common characteristics [1]:

- Networks composed of a variety of entities (organizations and people), which are autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals.
- Participants collaborate to (better) achieve common or compatible goals.
- The interactions between participants are supported by computer networks.

The general term to refer to those distributed collaborative organizations is collaborative-networked organization (CNO). As said previously, in CNOs, participants collaborate in order to achieve a common goal or similar goals. This goal usually consists in solving a problem by improving knowledge in a particular area. Knowledge in such a context is highly valuable and has to be captured in order to be reused in future collaborations. Thus, one of the most relevant issues in CNOs is knowledge management (KM). Thus the questions to address are the following: what kind of knowledge is to be managed in this context? How can it be capitalized properly?

The aim of this paper is to introduce our work concerning a system for conceptual knowledge management in virtual organizations by positioning it towards an existing system named n-dim. The first section deals with a characterization of collaborative R&D projects. In the following section, an information and knowledge management system named n-dim, which addresses a similar problem as the one we focus on, is introduced and presented. To finish, the last section is a presentation of a system proposal stemming from our work on knowledge management during the early stages of a R&D project. In this section, a comparison between the two systems is established to show their similarities, differences and complementarities. The methods and tools are being developed, tested and then used in engineering and research projects carried out by the network of excellence VRL-KCiP.

2 DISTRIBUTED COLLABORATIVE R&D PROJECTS CHARACTERIZATION

2.1 Assignments of R&D

R&D consists in "discovering new knowledge about products, processes and services, and then applying that knowledge to create new and improved products, processes and services that fill market needs"[1]. This definition highlights the two main sides of R&D: on the one hand, new knowledge production implied by research and, on the other hand, the reuse of this new knowledge in order to develop new applications. In this paper, the early stages of a R&D project are focused on, that is to say new knowledge production. However, the fact that this new knowledge is to be reused afterwards has to be kept in mind.

2.2 Distributed R&D characterization

A R&D project is composed of a team of people and a common objective (developing a new product or service, improving a production process, etc.). The companies people work in are also implied. But in virtual enterprise, the team of people is not a traditional working group: in this context, teams are virtual teams. Indeed, in a traditional working group, people are often brought together in order to work. In a virtual team, people are geographically distributed, consequently face to face situations become scarce. Due to this difference, virtual teams need a technological support for the team members to be able to work together. They need an informational environment by way of place (for information sharing) and a technological infrastructure by way of time (for asynchronous communication) [2]. To sum up, virtual teams require technological means to free themselves from place and time constraints. Additionally, the teams are composed of people with different cultures, practices, skills, tools, etc. In the next section an existing system dealing with a similar problem is introduced.

3 LITERATURE: THE N-DIM RESEARCH PROJECT

The n-dim project is a system and a research approach that aims to study and improve design taking into account that "design is a social process" [3]. The system particularly focuses on information management in engineering design. The aim of this section is to give a short overview of the project and the system by presenting the motives of this work, the features and the main concepts of the system.

3.1 Background

This approach has been influenced by empirical studies and documented observations concerning the nature of engineering work. From this material, Subrahmanian et al. [3] extracted a set of characteristics regarding the engineering work context. Some of those characteristics are the following: engineering activities usually extend over long periods of time, take place in multiple locations. In a given project, engineers often come from different cultures, have different practices and multiple languages or terminologies. Moreover, they use different tools or methods and deal with multiple areas of expertise, disciplines or tasks. This wide range of variety and complexity makes the design activity very difficult. In this context, information management is very complex but mandatory. In order to address this problem, the n-dim group developed a system for information modelling and tools integration during the design process.

3.2 Short overview of the n-dim system

N-dim is a design support system, which aims to support individual as well as collective evolution of knowledge all along the product development stages. The hypothesis of the n-dim research group is

[1] From the online dictionary http://www.investorwords.com.

that capture of structuration and evolution of information and knowledge must be done thanks to a generalized graph modelling environment that operates over all the elements (information elements and other information structures).

N-dim is a layered structure [4] that enables intensive storage steming from engineering activities. It can handle very large applications by separating the space in which objects are stored and the space where the objects attributes are stored. Finally, n-dim can handle many organisationnal structures through *cells*. Cells can be configured in many different ways and enable a distributed configuration for different users.

Thus, n-dim is based on graphical modelling and facilitates information structuration and visualization. This system enables the designer to build his own models using universal language or personalized language. The building of those models is based on objects that can be linked together, which provides a high flexibility to the system. Thus, by creating his own languages and models, the designer can create his own prototyped tools. Moreover, the n-dim system enables tools integration and knowledge acquisition thanks to history capture all along the design phase.

3.3 Main concepts

The n-dim system is based on three central concepts [3]: information objects, models and flat space.

- *Information objects.* There are two types of information objects: atomic and structured objects. Atomic objects are not decomposable (strings, images, numbers, media fragments, etc.). Structured objects are graphs which nodes are atomic objects or other structured objects. The graph comprises labelled links that relate objects to each others.
- *Models*. In the n-dim project, models denote both atomic and structured objects. Objects are referenced in model rather than being embedded in a model. In other words, models imply object association by having their pointers collected together. Named links are used to describe the relationships between the object pointers.
- *Flat space*. Flat space is an information space that contains the models. In this space, any user can create model by defining relationships between information objects. There exist three different types of spaces: private, public and published. Private space is individual and has no management restriction. The private space owner is free to delete or restructure the space. The public space is a kind of public forum. This space allows participants to share models and collaborate on those models in a synchronous or asynchronous way. Published space is an archival facility. The project history is captured in all these different spaces.

Modelling languages that are used in n-dim can either be informal or formal. The most informal usable language is the universal modelling language. Any objects can be linked with any other object by any link. In that way, informal models are very close to concept maps (see section 4.1.1). This language can be constrained and thus can strive for formal languages. The user chooses the constraints (properties, attributes) and thus can build his own language. Rule modelling languages can also be used, that is to say predicate and consequence structures based on basic events (objects and links creation or deletion). All those elements make the n-dim system be simple to use, highly flexible and thus very powerful to build all kinds of model.

4 SYSTEM PROPOSAL FOR MANAGING DISTRIBUTED COLLABORATIVE R&D PROJECTS

The n-dim project deals with R&D and more especially with design. It can be used either individually or collaboratively. In such a context, the designer’s main need is to modelize (activities, processes, products…). In our context of research network, the need is to support new knowledge creation (individual or collective) by externalizing it. Then, in both cases, knowledge has to be capitalized. In the following sections, the system that we are developing in order to manage knowledge in the early stages of a R&D project is presented and compared to the features and concepts of the n-dim system.

4.1 Approach

It is usually considered that there are two kinds of knowledge: explicit and implicit knowledge [5]. Explicit knowledge is embedded into written documents (e.g. research publications, reports, etc.). Tacit knowledge is in people’s mind and is acquired through experience; it is very hard, even impossible to make it be explicit. In addition, during the research stages of a R&D projects, people continuously juggle with existing knowledge (state of the art, technology watch…) and emerging knowledge (stemming from the research project). Thus, in our context, all those aspects of knowledge are needed to be managed. In the following subsections the basic concepts of our system are introduced, how they address the knowledge management problem and how they extend or differ from the n-dim project.

4.1.1 Shared concepts with the n-dim project

During the collaboration, experts have to work altogether and to combine their individual knowledge in order to create new knowledge. An interesting tool that can support this kind of task is concept maps (see Figure 1).

Concept maps are diagrams that represent organized knowledge [6]. Coffey and al [7] identify four main characteristics concerning concept maps: First, concept maps are composed of concepts and relationships between them. Concepts are defined as “a perceived regularity in events or objects, or a record of events or objects, designated by a label”. They constitute the nodes of the graph, they are often represented by a labelled box or circle. Relationships, the arcs of the graph, are represented by connecting lines that link two concepts together. Those connecting lines include a label, word that specifies the relationship. A triple concept-link-concept is called a proposition, which is a meaningful statement (often called a semantic unit). The second characteristic of a concept map is that concepts are organized in a hierarchical way: the most general concepts are at the top of the diagram while more specific concepts are arranged below. The third point deals with cross-links. Cross-links are relationships between concepts of different regions or domains within the concept map. This point is very significant for knowledge creation because that kind of link often represents creative leaps for the knowledge producer. The last characteristic is the possibility to include examples or specific objects in order to make the meaning of a concept clearer.

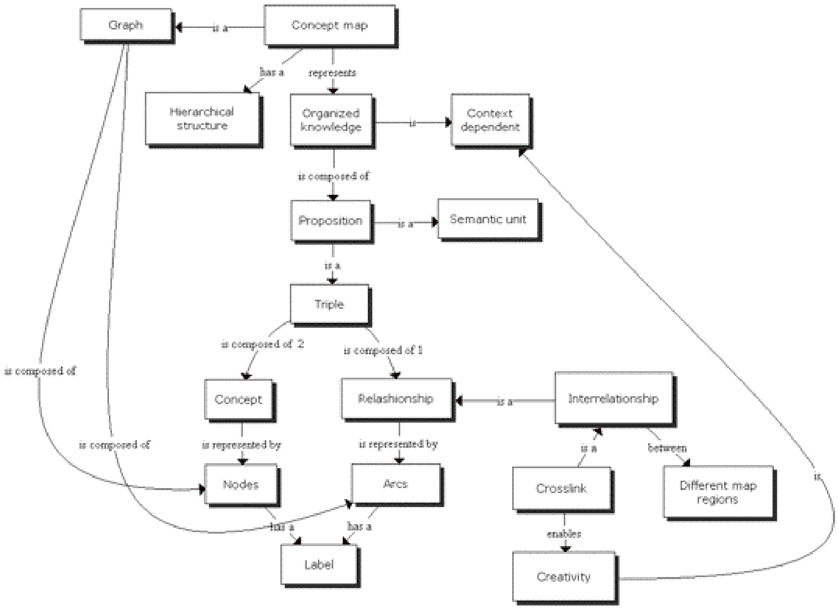

Figure 1. A concept map about concept maps

In the field of knowledge management, concept mapping is considered as a useful vehicle for externalizing tacit knowledge (embedded in experts mind) and to allow this knowledge to be examined, reused and refined. Indeed it is a useful graphical support for sharing and discussing. Some tools based on concept mapping have already been developed in order to provide interactive capture, access and application of knowledge representing different expert perspectives [8].

To conclude, we chose to use concept maps because it is a graph based modelling tool that enables organizing and structuring knowledge visually. Concept map is an easy to use modelling tool, which is very flexible thanks to the use of universal language. Thus, both n-dim and our KM system are object-based. In that way, the system proposed is very close to the n-dim project and particularly to the public information space. Indeed, concept maps are built in a collaborative way in our system. Public information spaces of n-dim enable synchronous or asynchronous collaboration on models too. The differences between the two systems particularly lie in their use and their architecture. The system developed is based on additional concepts.

4.1.2 Special requirements and solutions

In order to capitalize and manage explicit knowledge, building a collection of documents is needed. Yet, knowledge resulting from past work is embedded into written texts and schemas, which does not facilitate finding appropriate knowledge and reuse it: reading the whole document is necessary just to find a piece of information that interests or sometimes nothing. So the documents content has to be modelled in another way in order to make knowledge easily findable and reusable.

The inclusion of tacit knowledge in a knowledge management system can be done through knowledge mapping [9] and users profiling [10]. A competences profile is associated to each member of the organization so that it is easy to find people owning the appropriate knowledge [11]. Indeed, finding appropriate partners for collaboration within a short time is of key importance for a CNO, especially in business context [12]. Yet, it shall be kept in mind that competence profiling, in the context of a KMS, must be easy to build and to maintain. Actually, the system should require minimum effort and time from the user, otherwise it would neither be up to date nor used.

A common knowledge base is the core of the system to manage and integrate all those tools. The most efficient way of creating a knowledge base is to use ontologies [13]. Ontology is considered to be a powerful means to represent knowledge through the concepts of a specific area and the relations between them. Ontologies are generally represented by using a wide variety of logical languages, understandable both by human beings and machines [14] such as propositional logic, first order logic and Semantic Web languages. In this paper we chose to focus on the languages stemming from the Semantic Web, the new standards developed by the W3C, considered as the future standards of the Internet. Actually, the ontological approaches for information exchanges on the Internet has to be considered in the next generation of KM systems [15], especially for CNOs since the WWW is the most easy and accessible way of exchanging information.

4.1.3 System concepts

Table 1. Tools and knowledge management

Knowledge	Existing	Emerging
Tacit	Profiles	-
Explicit	Document database	Concept maps
+ Semantic Web tools		

Table 1 sums the previous subsections up. Indeed, it shows the tools chosen to be used to manage the different categories of knowledge identified above.

Thus, our system is based on a knowledge base (see Figure 2). This knowledge base is a domain ontology that covers the domains of interest of the CNO. Everything in the system is linked to this ontology so that everything can be retrieved browsing the ontology. The implementation is done thanks to the semantic web tools, which enable ontologies building and sharing over the web. Concerning the profiles, each user has a profile describing his competencies. Those competencies are linked to the domain ontology in the knowledge base. This profile is automatically and dynamically updated over the collaborations (see scenarios in section 4.2). Concept maps are built by the collaborators. The concept map of the project is one of the key concepts of the system. Indeed, it will be used to extend the ontology (after an RDF[2] translation) and to link all the documents and the profiles of the project to the ontology. A document database is used to store all the objects (documents, files, media, etc.) of all the projects. Each document is linked to the ontology thanks to RDF annotations.

[2] Ressource Description Framework

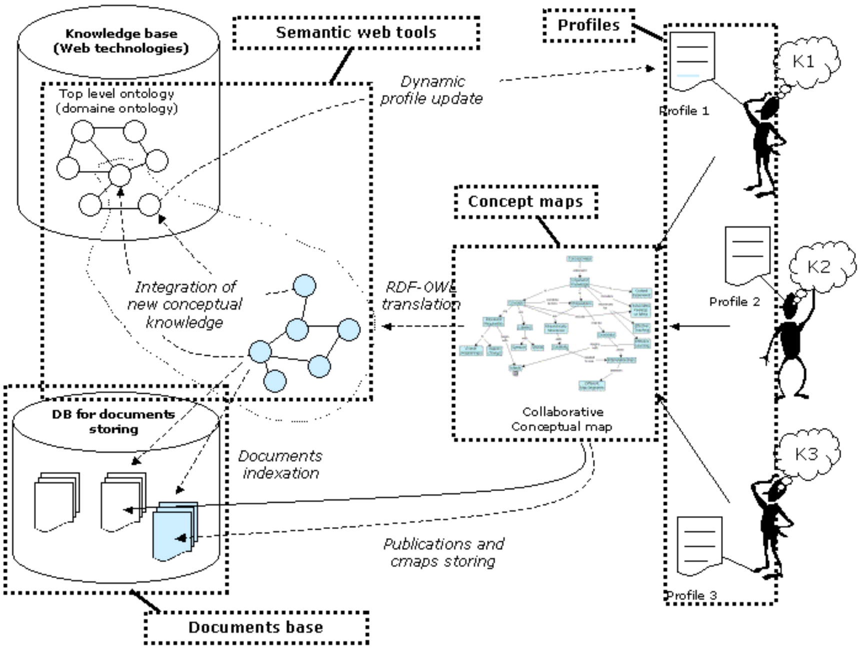

Figure 2. System framework

4.2 Scenarios

The aim of this subsection is to introduce the usage of our system. In this introduction, we only focus on how to capture knowledge and then how to update the knowledge base as well as the profiles. In order to clearly achieve this, our explanation is based on two different scenarios. The first scenario illustrates the case of the first collaboration of a partner in a completely new project. The second one deals with the case of a partner who already collaborated in one or more previous projects. In this case we consider that the project is quite similar with a previous project.

4.2.1 First collaboration scenario

Let us consider a new R&D collaboration project. The team is composed of 3 people and at least one of these people is a new partner, that is to say it is his first collaboration in this virtual organization. Step 1 (see Figure 3), the new collaborator has to manually fill in his profile depending on his competences. Step 2 consists in building a concept map collaboratively (in a synchronous way). This map is used to model the project and organize the key concepts and other objects (documents, web links, other medias…). It must provide a shared view and understanding of the project for the collaborators. Once the concept map is built, the project can be executed. During the project execution stage, some documents are produced. The map can help producing those documents. During this stage the map can be slightly modified. All the documents resulting from the project are stored in a database (step 3).

Once the project ends, the last version of the concept map is translated into a set of RDF statements representing the project (step 4). The nodes of the RDF statements are linked with the concepts of the domain ontology (step 5). All the project documents are annotated with the RDF statements (step 6), even the concept map, which is a document. Thus all the documents are linked with the upper ontology. Those links will allow documents retrieval by browsing the ontology in future projects (see second scenario). Finally, the collaborators profiles are annotated with the RDF statements and thus are linked with the ontology too. The profile is dynamically updated with each new project.

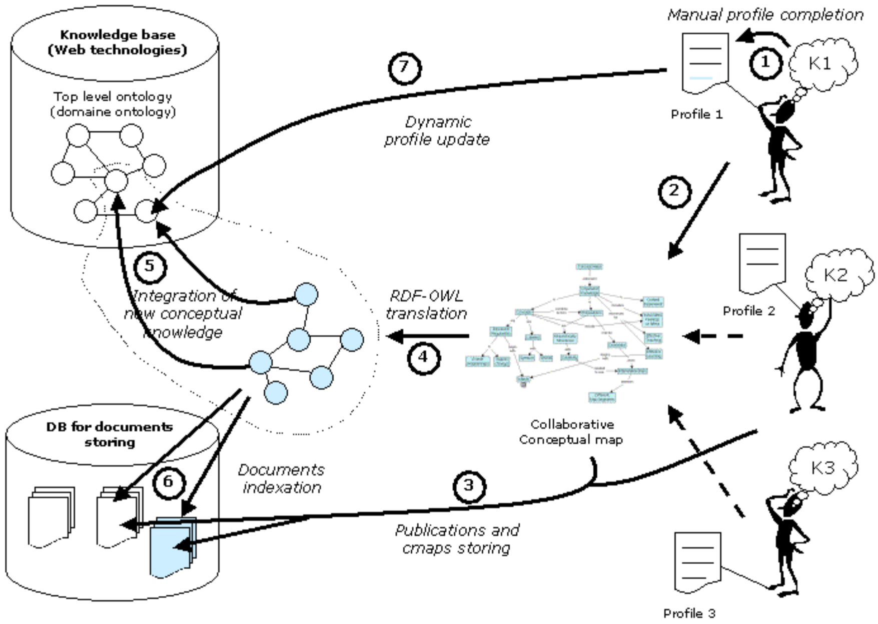

Figure 3. Scenario of the first collaboration of a partner in a completely new project

4.2.2 Second and other collaborations scenario

In this second scenario, let us consider another new R&D collaboration project. Yet this new project has some similarities with one or several past projects. The team is still composed of 3 people but in this case, every partner has already worked and collaborated in this virtual organization. Figure 4 illustrates this scenario. Dotted lines in Figure 4 represent the steps that are common with the first scenario.

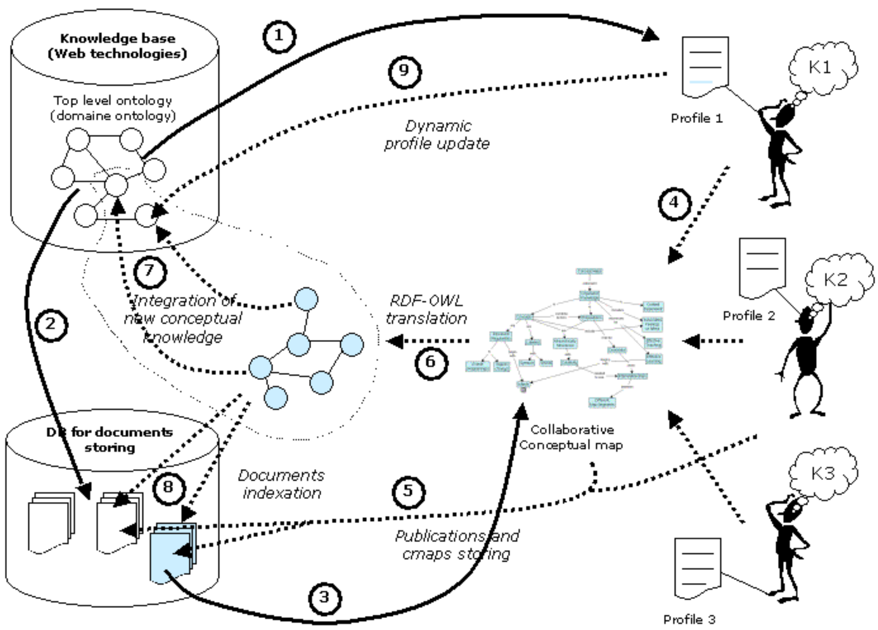

Figure 4. Scenario of the second collaboration of a partner

Step 1: for a given project, people to be hired can be found thanks to their competencies profile by browsing the domain ontology. Once the team has been gathered, the project can start. The collaborators can browse the domain ontology, which can lead them to similar past projects and thus to interesting documents (step 2). Thus, those documents can be useful for the project and one can even find and use an existing concept map as a basis for the new project, since a concept map is a document (step 3). Then, steps 4 to 9 of this scenario are similar to steps 2 to 7 in the previous scenario. That is to say that the team collaboratively builds the concept map representing the project. Then the documents resulting from the project execution are stored in the database. At the end of the project, the concept map is translated into RDF statements. Those statements are linked with the domain ontology and are used to annotate all the documents of the project (even the concept map). The collaborators' profiles are automatically updated with the RDF statements.

5 CONCLUSION

The big issue, in collaborative networked-organizations, is to capitalize and manage knowledge produced over collaborations. Here "knowledge" means explicit knowledge as well as tacit knowledge. In order to achieve this goal, we have introduced an existing system named n-dim and another system developped in the VRL-KCiP context based on several concepts. The concepts of the system developped in the VRL-KCiP context are following. The first concept is, concept maps. Indeed, concept maps help to express, share, organize and capture tacit knowledge of expert people. The second concept is a knowledge base using Semantic Web technologies. This knowledge base aims to integrate new knowledge, index and store all the documents related to this new knowledge. The last concept is dynamic profiling: it enables to index tacit knowledge of expert people through competence-profiles and dynamically update those profiles depending on the contribution of experts over collaborations.

Therefore, we propose a dynamic system that is able to capture and capitalize explicit as well as tacit knowledge during the research stages of a R&D project. From now, further work consists in detailing the use of the knowledge base and the best ways of reusing the capitalized knowledge. The system, methods and tools are being developed, tested and implemented in engineering and research projects carried out by the network of excellence VRL-KCiP.

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