

FRAMEWORK FOR A KNOWLEDGE SUPPORT SYSTEM FOR DISTRIBUTED COLLABORATIVE DESIGN PROJECTS

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Engineering design projects are more and more often developed in network of R&D services of several companies. It is particularly the case of projects developed in the context of European Network of Excellence (NoE) grouping together 24 teams of expert researchers in the mechanical production field over 15 European countries. Such a research network is characterized by assignments that are detailed in the paper. One of them is new knowledge creation; it represents the core of the network assignments. Some tools already exist in order to support other assignments but no tool can support this one today. In this paper, we aim to characterize the process of new knowledge creation in collaborative and distributed scientific research context. Then we suggest some specifications and a framework for a system to support the creation of new knowledge in a context of distributed collaborative project of engineering design.

1. INTRODUCTION

Nowadays, worldwide economy and competition often lead companies to set up temporary alliances with other companies. Those alliances enable product or service development within a short period by making the best use of all the available resources (people, data, hardware, software...). This distributed structure, is called Virtual Enterprise (VE) (Harwick, 1997) and is supported by an interconnected information network. This computing environment is mandatory for the virtual enterprise to exist. Indeed, it enables collaboration between all the participants wherever they are located in the world. Our interest in this paper is focused on the early stages of a research and development (R&D) project in a virtual enterprise. We aim to analyze how new knowledge is created in such a context and how it is or it should be supported.

In section 2, we try to characterize a R&D project in a virtual enterprise by identifying its assignments and the existing tools that can support each of those assignments. Section 3 deals with the activity of knowledge production in such a context. We identify the requirements to support this activity. To finish, we suggest, in section 4, a framework for a system supporting knowledge creation in virtual enterprises R&D projects.

2. R&D PROJECT CHARACTERIZATION IN A VIRTUAL ENTERPRISE

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”ⁱ. 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, we focus on the early stages of a R&D project, that is to say new knowledge production. However, we have to keep in mind that this new knowledge is to be reused afterwards.

2.2 Distributed R&D project and virtual teams

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. Thus, what does make a virtual team different from a traditional working group?

The main differential factor lies certainly in face to face situation (Coat, 1998). 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 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). To sum up, virtual teams require technological means to free themselves from place and time constraints. Nevertheless, technology does not solve all the problems, it brings new difficulties too. Moreover as explained afterwards, time constraints cannot be always avoided due to some activities that require synchronous work.

2.3 Tools for supporting collaborative work

Some tools for supporting collaborative work already exist. Concerning information sharing, there exist file sharing applications, collaborative word processors, collaborative portals (such as wikiⁱⁱ websites), group calendars, etc. or applications that gather all those functionalities. Regarding communication tools, emails and forums enable asynchronous communication whereas chat, videoconference, telephone, voice IP enable synchronous communication. In this category, there also exist software for application sharing.

All those tools can support communication and collaborative documents gathering or building but none of them can really support knowledge production as defined in next section.

3. KNOWLEDGE PRODUCTION IN SUCH A CONTEXT

Knowledge production consists in series of tasks. Once the team is constituted and the common objective and individual roles are clarified, a research project often begins with grouping literature about existing knowledge of the concerned domain. Then a synthesis is written in form of state of the art. Then, a brain storming task is launched in order to catch all the new ideas of all the participants, followed by a selection task in order to collect the adoptable solutions. Among those tasks, it is possible to identify two categories: open tasks and closed tasks (Coat, 1998).

Brain storming and grouping literature are *open tasks*. That is to say that all the individual contributions are additive. It is an accumulation of documents and ideas. This task can be a synchronous or an asynchronous task. It can be modeled by an opening funnel (see Figure 1). On the contrary, synthesis and especially selection tasks are *closed tasks*. The team has a group of ideas, data and information that has to be reduced. The addition of all the individual contributions cannot constitute the solution of the group. It can be modeled by a closing funnel (see Figure 1). Thus, for closed tasks, negotiation between the team members is necessary to find the group solution. As a consequence, it has to be a synchronous task so as to enable discussion.

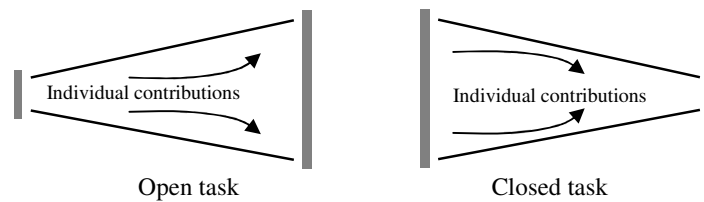


Figure 1 – Open tasks and closed tasks (Coat, 1998).

For open tasks, ideas can be stored in documents and collected with a file sharing system so that every team member can consult all the documents. Distant meetings (videoconferences) can be organized for each member to present his ideas to the whole team. The problem is that all the ideas are embedded in the documents (often text documents). The accumulation of documents does not provide a big picture of all the suggestions and then the selection task is very difficult. Thus, knowledge production requires a specific support in order to facilitate the emergence of new solutions, therefore new knowledge.

4. FRAMEWORK PROPOSAL FOR A SYSTEM SUPPORTING KNOWLEDGE PRODUCTION IN DISTRIBUTED R&D PROJECTS

4.1 Requirements for supporting knowledge production

As we explained in the previous section, what we need here is a support for the knowledge production stage. As a consequence, this support has to enable knowledge representation. Moreover, in our collaborative context, this support has to enable discussion between individuals and negotiation around existing knowledge and emerging knowledge (especially for the closed tasks we have introduced above).

Those two specifications lead us to the concept maps (or conceptual maps). A concept map is a tool that is used to represent knowledge in a visual way. As we said in section 3, knowledge is usually embedded in documents and mainly in textual documents. The difficulty with such documents is that knowledge (concepts, ideas...) is drowned in the text. It is always more difficult to discuss about a text than about a diagram, a draw or a schema. Thus visual representation makes discussion be much easier.

Our idea here is to use concept maps in order to represent existing knowledge and new ideas extracted from different documents and to merge everything into one visual representation. Thus, it would be simpler to discuss and determine what is connected to what and to build new knowledge on this basis.

4.2 Concept maps

Concept maps are diagrams that represent organized knowledge (Novak & Gowin, 1984). Coffey and al (Coffey, 2003) 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 labeled 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.

Thus, this kind graph seems to be very interesting to represent knowledge and support knowledge creation in our context. Indeed, this tool is a semi formal graph that is flexible enough to make the visual representation of every kind of knowledge possible, it includes semantic, it allows knowledge creation by facilitating the identification of new relationships between concepts and, to finish, it makes it possible to add specific objects (instantiations of concepts) to support meaning. Next section provides an example of technical knowledge representation through concept map.

4.3 Example: technical knowledge representation

In order to illustrate and validate our ideas, our first trial consists in translating an article about vibratory drilling (Peigne, 2005) into a concept map. We chose this paper because it stems from a very technical work, the kind of work that could presumably be lead in a R&D project. Furthermore, this paper is very rich concerning existing and new knowledge. It is thus interesting to test whether concept maps are suitable for structuring and representing such an amount of knowledge.

The concept map that stems from this paper is shown in Figure 2. Hatched boxes represent the most general concepts of the map. White boxes are the existing concepts and grey boxes are the new concepts introduced in the article. This figure gives a rough idea of the complexity of the whole map: it is composed of 39 concepts and more than 40 links. Yet, this map is not complete. It indeed represents only a small part of the knowledge embedded in the paper, details are missing. We decided to stop building this concept map because it became unreadable and unusable. Yet, the analysis of this concept map gave us good results.

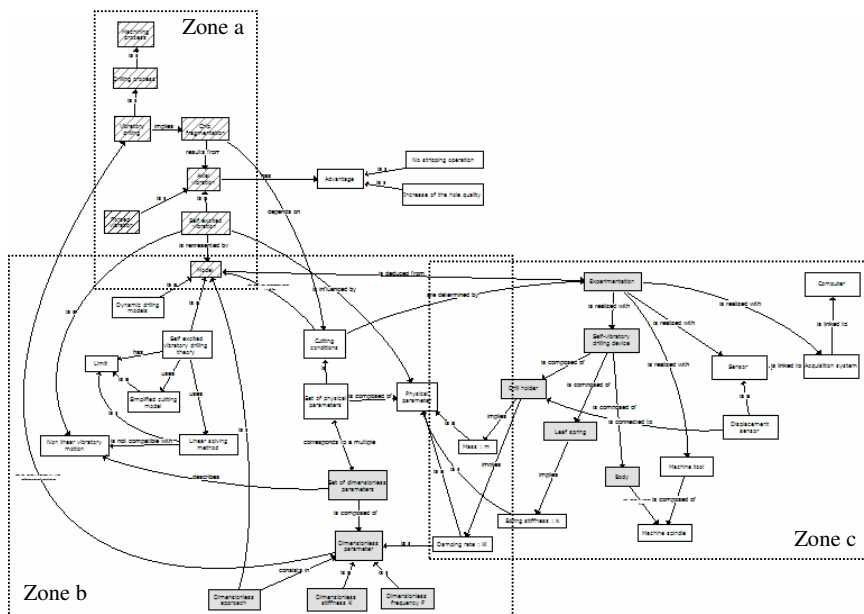


Figure 2 – Conceptual map representing knowledge extracted from (Peigne, 2005)ⁱⁱⁱ.

In figure 2, the map is divided into three zones to facilitate the analysis. Zone a gathers the most general concepts (see figure 3 for details). Those concepts enable the reader to fix the context of the knowledge represented in the map. In the example, we know that knowledge is about a machining process and more precisely a drilling process: vibratory drilling, which causes chip fragmentation, etc. We can

imagine that those general concepts could permit to connect this conceptual map to a domain ontology in the context of a knowledge management system.

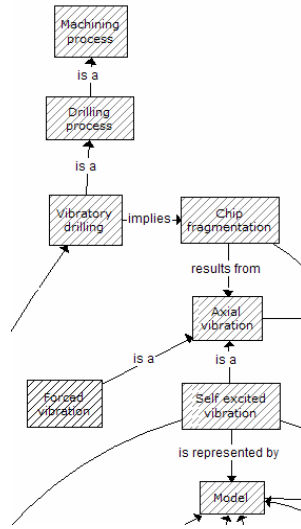


Figure 3 – Zone a: the most general concepts of the concept map.

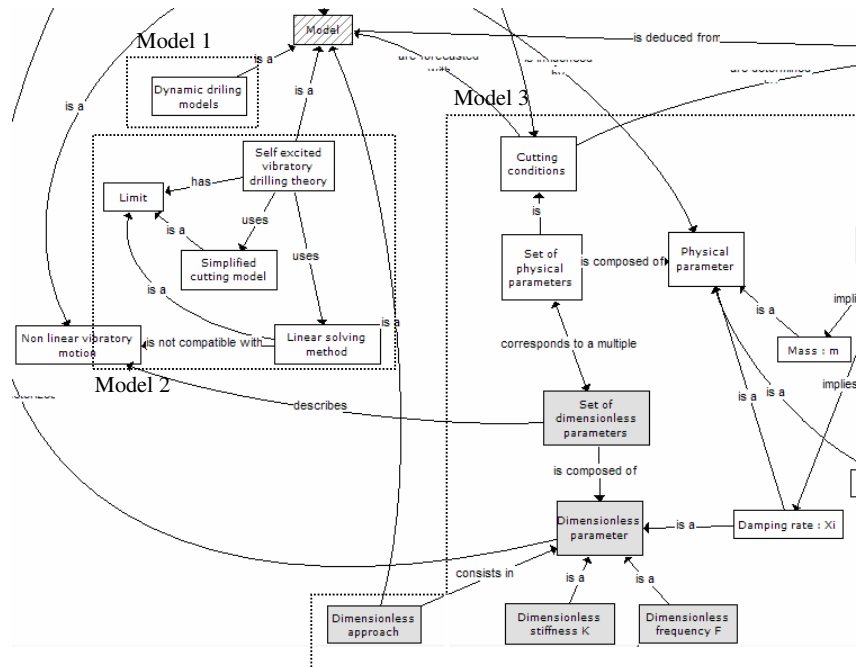


Figure 4 – Zone b: Conceptual representation of the models presented in the paper.

Zone b gathers the representations of the different models presented in the (Peigne, 2005)^{iv}. They are not represented the same way, depending on the level of details given in the text. Three models are presented: dynamic drilling model, self excited vibratory drilling theory and the dimensionless approach. The latter model is the core of the paper. Those three models are differently represented and we could say that there exist as many possible representations as concept map designers. A consequence is that this kind of representation does not make knowledge easily reusable afterwards. The problem is that the concept entity is a too small unit and people can organize them differently in concept maps even if the represented knowledge is the same. The case is the same for zone c which gathers all the concepts used to represent knowledge about the experiments presented in (Peigne, 2005). However it is possible to identify permanent features in knowledge representation about models or experiments that leads us to the concept of *brick*.

4.4 The “brick” concept

As we said above, by analyzing the paper about vibratory drilling in details, it is possible to identify permanent features in models or experiments representations. For example, a model can be represented with the following structure: a physical model based on a simplification of reality (schematic representation), on hypothesis and defined on a validity domain; the mathematical model (that stems from the physical model), which is composed of governing equations, which made of mathematical parameters and variables and those mathematical parameters and variables correspond to physical parameters. Thus it is possible to build an entity with a set of pre-structured concepts in order to represent a physical model (see Figure 5). A similar analysis leads to the same kind of structure for knowledge representation about experiments (see Figure 6). Thus, what we call *bricks* are boxes with pre-structured concepts inside. Moreover, those bricks are not independent; they are connected to each other. For example, we identified that the model brick and the experiment brick are connected to each other with the physical parameters.

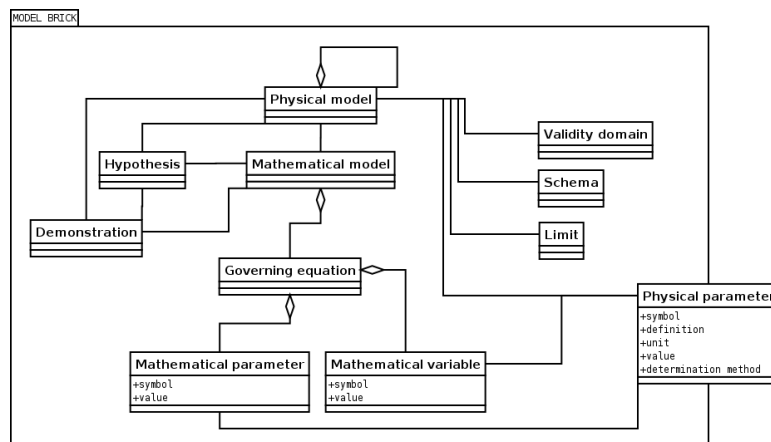


Figure 5 – UML schema of the Model brick.

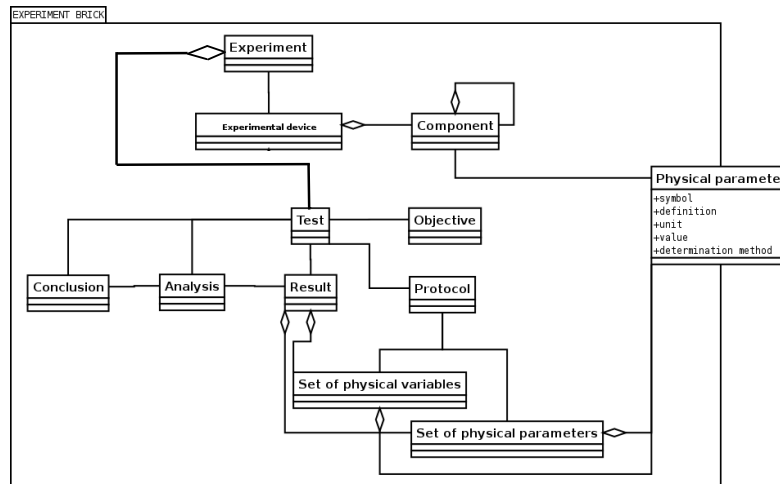


Figure 6 – UML schema of the Experiment brick.

5. CONCLUSION

In this paper, we identified the need of a specific tool that could support knowledge production. Concept map is a known means for representing knowledge. As a graphical tool, it seems to us that this tool is a good basis to support knowledge production by its capacity to give a big picture of the domain showing how everything is or should be related. We have experimented concept map in order to represent highly technical scientific knowledge. This led us to a concept map that was far too complex to be readable or reusable afterwards. Thus, we found a means to enhance concept maps with sets of pre-structured concepts in order to represent specific kinds of knowledge (knowledge about experiments or physical models) in a systematic way that makes it reusable afterwards. Those bricks can be connected to each other and to the most general concepts of the concept map that fix the context.

To conclude, in this paper we started from knowledge representation to finally merely focus on the framework of the system, that is to say how knowledge can be stored and not really represented. Indeed, the bricks are only structures, not real representations of knowledge. We now have to identify and build other bricks that represent knowledge about simulation or empirical laws for example and see how those bricks are connected to each other. Then we have to build a user friendly GUI (Graphical User Interface) that will enable a readable and usable view of the represented knowledge. Indeed, we have to keep in mind that this tool is a support which has to “help” people creating knowledge collaboratively.

ⁱ From the online dictionary <http://www.investorwords.com>.

ⁱⁱ A wiki is a piece of server software that allows users to freely create and edit Web page content using any Web browser.

ⁱⁱⁱ This concept map has been drawn with MotPlus, software edited by the LICEF research center : <http://www.licef.teluq.quebec.ca>.

^{iv} The models are not complete as we said before, because of the complexity of the map. In this instance, equations, hypothesis, etc. are not included in the map.

6. REFERENCES

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