A Cognitive Engineering Approach to the Design of a Web-based Cooperative System

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Abstract

We address the design issues of a cooperative environment, called COOPARENA, implemented into a portal (named MAGIE) which supports the technological innovation process in the automotive industry. This upstream process takes place in an extended firm which is characterized by collaborative work by geographically distributed team members. Besides face-to-face technical work or management meetings, these teams need to get access to a collaborative web environment that allows the collective tasks of the project to be performed in an asynchronous way. Our design approach is based on cognitive engineering principles. From this standpoint, we first carried out a cognitive ergonomics analysis of the current collaborative situations, either synchronous (e.g. management or technical working group meetings) or asynchronous (e.g. emails, forums or document publications), in which the team members are involved. This ergonomic analysis resulted in a cognitive model of the cooperation space, named COOPARENA. The second step of our approach consisted of translating this model into UML use cases. This was carried out in close interaction with the system designers, making it possible to structure the architecture of the cooperation environment in such a way as to meet the real needs of the Web-based collaborative platform's future users.

Keywords: Web-based collaborative system, virtual team, technological innovation, cognitive engineering, use cases, UML

1. Assisting the technological innovation process in extended firms

Technological innovation, in the automotive industry as in other industrial sectors, is nowadays a key factor in ensuring company viability by developing new products as well as providing new services. Examples could include mobility services offered by the introduction of internet-based technologies in a vehicle: navigational assistance, route planning aids, telebooking of cultural events, provision of tourist information, transportation, etc. Today, this innovation process shares a particularity with many fields of activity. It takes place in the framework of an "extended" firm and brings together, for the duration of a project, a number of geographically distributed actors from a variety of professional fields, whose individual involvement in the innovation process will vary considerably. The inner circle will contain those actors directly concerned with the project and its successful completion: the manager, internal or external specialists, and the persons in charge of monitoring technological advances and handling corporate knowledge. Associated with this group will be a larger circle of experts whose particular skills will be needed according to specific technical requirements. The outer circle, which is out of our research focus, contains all stakeholders on whom the innovation has an impact, belonging to a "value constellation" [14].

For the actors of the first two circles, it is becoming crucial to have access to Web-based collaborative environments that can support all of their cooperative activities. This need is particularly felt at the outset of the innovation process, when the major part of the partners' activities consists of “collecting, analyzing and providing all the information, knowledge and know-how necessary to reach the decision to innovate” [21].

Monitoring this decision-making process involves very strong demands for cooperation. The first one is to support the articulation of work [19] by providing innovation team members with coordinative artifacts. A number of available CSCW tools play this role: structured content management tools, forum, notification tools, calendars, charts, etc. These artifacts enable the actors of the innovation process to manage the operative and temporal synchronization required by the interdependencies of the tasks [7].

But in many cases, the interdependencies of tasks require more than an operative articulation of work. Project partners have to perform co-design activities [7] during which they must operate a cognitive synchronisation on the problem. This is a question of monitoring the problem-solving process itself [18] and the issue is to achieve it with very strong constraints of direct cooperation. These cooperative activities among actors with specific competences and different seniority require communication channels and structures [3] through which the actors can negotiate, argue, debate and compare their viewpoints about the documents related to the project (technical documents, deliverables or product specifications).

For these reasons, it is not enough for distributed design teams involved in an innovation process to have a common place where work could be accessed and archived. They need to have efficient supports in their day-to-day cooperative activities so as to work collectively from remote locations in both synchronous and asynchronous modes. In some respects, it is a question of extending and enhancing the existing Web-based collaborative platforms to assist tightly coupled work activities.

2. Diversity of CSCW systems to support the innovation process

The existing CSCW systems that support the innovation process do not adopt the same approaches of the assistance needs. Some of them focus on assisting the synchronous or asynchronous interactions related to creative phases of the innovation process. Others give greater importance to enhance the mutual awareness of the asynchronous interactions. Some others focus on providing integrated tools to run the various activities related to the innovation process. Our approach belongs to the last approach which consists in designing collaborative *task-oriented* environments.

- *Focusing on assisting the creative phases of the innovation process.* Some systems pay particular attention to the creation process and to the brainstorming phases arising during the innovation process [15]. The i-LAND system [22] is composed of an interactive electronic wall that presents the objects, an interactive electronic table to manipulate the objects and interactive tools to support brainstorming and project management. The BEACH system [23] aims at supporting the creation process with three tools, either during synchronous or asynchronous phases.

- *Focusing on supporting the mutual awareness.* Because of the strong interdependencies of the innovation tasks, any change in the field of the work will affect the work of others instantly [3]. Members of a distributed team should stay aware of these modifications [8, 11].

- *Focusing on running the whole innovation process.* The idea is to support all of the various activities related to the innovation process [8,12], either be collective (e.g. face-to-face or virtual meetings) or individual (e.g. browsing minutes meeting or technology survey). f the top of all, it is not given greater importance to asynchronous interactions: the efficient articulation between synchronous or asynchronous teams’ activities is considered as a key factor of success. This is what it is proposed with PIM [5]. The system offers a function to gather internal information (generated by the team of creators) and external information (complaints, requirements, problems) allowing this information to be translated into product functionalities or into projects to design new products. The projects are ranked according to the aims and constraints of the organization. Each step of the innovation process (client feedback on the products, strategic planning for innovation, communication of the corporate strategy, formulating and managing ideas, sorting proposals, identifying relevant innovations, managing tasks, product reviews, etc.) corresponds to one module of the system.

Similarly, [1] propose a system to enable persons who have worked on identical subjects to share a common work space. The system allows users to identify an interesting topic or problem, to ask questions and make assessments. It makes it possible to locate other users who have the same concerns. A search for information in a database that is regularly updated from various sources (Web sites, books, journals, etc.) is provided.

- *Focusing on providing a collaborative task-oriented environment.* A Web-based environment for distributed teams should be task-oriented. The issue is to “combine various collaboration technologies into a user-centric system that is integrated into the work process of team members” [8]. This consists of making use of some classical functionalities of CSCW (agendas, forums, document publications, notification, etc.) and combine them on the basis of a collaborative task model. In AWMS [13, cited in 3], the tasks are modeled by requests and expressed in a workflow composed of actors, procedures, information, tasks and management.

The principles that we adopted for the development of MAGIE, our Web-based cooperative environment, are similar to those that have just been presented. We have chosen to combine functionalities of classical CSCW tools (structured content editing, task management and coordination, management of access according to profiles, a forum, storing and sending messages using predefined lists) according to a structured cooperative task model. Compared with the previous system, the novelty of our approach lies in the strong structuration of this cooperation space. The collaborative trades are guided by a coordinative protocol. This script [20] allows to manage the task interdependencies of the innovation process (see §5).

3. Cognitive modeling of the cooperative workspace

Our approach comprised two essential phases. The first phase involves studying face-to-face non-mediated cooperation situations (§ 3.2), in order to identify and model the cooperation space. The second phase, carried out in close cooperation between computer specialists and ergonomists, is to translate this cognitive model of the cooperation space into use case diagrams, as formulated in UML (§ 4).

3.1 Description of the Cooperative Situations and Methodology

We observed the cooperative activities carried out during an on-going innovation project on the design of vehicle services (journey organization assistance, itinerary planning, emergency medical situation management, etc.). The partners in the project are from five companies or organizations (industrial user, suppliers and one research institute). 6 to 12 persons attended the meetings depending on the subjects dealt with. The frequency of the meetings is about one a month. The five meetings analyzed were held at the end of the first year of the two-year project and concerned the preparation of a multimedia presentation illustrating the progress of the project, to be presented at a professional trade show. The systematic data gathering was done by an ergonomist who acted as a non-participatory observer (audio recording and a double video recording).

3.2 Cognitive Modeling of the Cooperative Activities

3.2.1 Identifying six Collective Tasks Supporting the Innovation Process

Most of the cooperation activities are carried out during meetings which are structured by a certain number of Collective Tasks (CTs). These latter may deal with specific items on the agenda (e.g. "take stock of the progress of the work") or which may be more implicit (e.g. "examine a particular subject collectively"). The analysis revealed six types of CTs that structure the meetings. The length of these CTs varies (from 10 minutes to around 1 hour 30') and the number of persons involved fluctuates (from 2 to 10):

- [CT1] CREATIVITY PHASE: this consists of producing and pooling ideas in a brainstorming session (e.g. the projected use of a Webpad);
- [CT2] TAKING STOCK OF PROGRESS: this concerns verifying that the engagements are respected in terms of deadlines, resources, production or requirements (e.g. producing a deliverable, a software package, etc.);
- [CT3] EXAMINING A PARTICULAR SUBJECT: an open question on a topic relating to the project is examined by a group of actors (e.g. the choice of presentation for a trade show).
- [CT4] COORDINATING THE PROJECT: this task aims to organize the directions in which the group wishes and/or is able to follow (e.g. identifying and choosing the trade shows and conferences at which the project could be presented).
- [CT5] PRESENTING A SPECIFIC CONTRIBUTION: a partner presents a contribution to the other partners (e.g. comparing the functionalities offered by the Webpads on the market).
- [CT6] ASSESSMENT SESSION: this concerns presenting the results of the project (e.g. presenting a demonstration or a mock-up of the project to some fifty specialists, experts and decision-makers).

All the meetings observed can thus be described as a succession of CTs whose order and sequence are not predefined. These CTs can be characterized by their aims but they can also be distinguished according to the cooperative activities that are brought into play to achieve these aims, as shown in the following section.

3.2.2 Identifying eight Basic Cooperative Functions

Within each collective task, free participation is the rule. The main support for cooperation is speech which is sometimes backed up by examining documents or visual presentations (reports, transparencies, etc.). The very nature of these innovative design situations requires a dialectic confrontation of the points of view being built up by each of the actors. The speakers' contributions may be interrogative, affirmative, uncertain, querying, etc. The persons to whom the contributions are addressed vary: either one (or several) identifiable individuals, the group as a whole, or else the speaker himself. Several iterations are needed in the exchanges in order to enter into the subjects more deeply and deal with the issues raised. The various ways of communicating and cooperating that allow the CTs to be accomplished we modeled as a finite set of *Basic Cooperative Functions* (called *BCFs* in the rest of this paper). These *BCFs* are the basic units (or building blocks) to carry out the cooperative actions triggered during the meetings. The success of a CT in practice is based on the correct linking of several *BCFs*.

Eight *Basic Cooperative Functions* were identified in the meetings that we analyzed. The BCFs *Asking_a_question*, *Responding_to_a_contribution* and *Expressing_a_viewpoint* involves pooling and confrontating the different positions that the participants build up or modify, the actors expressing themselves in order to contribute to examining the choices. As we will see in the next section, these represent most of the spoken contributions in a meeting. The five other BCFs present a more formal undertaking by the actors in their exchanges. It is a question of initiating and directing cooperation (BCF *presenting_ content_to_exchange_viewpoints*) examining questions (BCF *Proposing_a_sub-discussion* and *Taking_a_decision*). The BCF Recentering_the_discussion is the prerogative of the project leader and aims to point out deviations from the project aims. Finally the BCF *Project_assessment*, little observed during the meetings, is applied in the framework of an external assessment of the results of the project.

3.2.3 Combining Basic Cooperative Functions (BCFs) identified during the five meetings

When carrying out a COLLECTIVE TASK, the team members bring some, but not all, *Basic Cooperative Functions* into play. As an example, we counted the various *BCFs* used during the 30-minutes CT3 [EXAMINING A PARTICULAR SUBJECT]. The participation varied greatly: 2 team-members took a very active role in the discussion (19 and 23 contributions), 3 members played a smaller role (6, 7 and 10 contributions), 2 members said very little (1 and 3 contributions) and 3 members did not speak at all An analysis of the results shows which *BCFs* are used for a given CT. Thus we can see that for CT3 EXAMINING A PARTICULAR SUBJECT, only five *BCFs* were used. Of these, three *BCFs* (*Asking_a_question*, *Responding_to_a_contribution* and *Expressing_a_viewpoint*) were used to a very great extent (90% of all the BCFs brought into play). This example shows that each CT is carried out by a specific combination of *BCFs*. We identified the various combinations, which allowed us to provide a model of each COLLECTIVE TASK, as presented in the next two sections.

3.2.4 Modeling COLLECTIVE TASKS

The analysis showed that the CTs are made up of a finite set of *BCFs* which are combined in specific ways. Figure 1 presents the various *BCF* configurations for each CT according to their frequency of use in real interaction (§ 3.2.3).

The results also go against the intuitive notion that the more constrained a situation is (due to a reduced number of functionalities), the less freedom the actors have in their exchanges. On the contrary, the results show that certain CT which are apparently loosely structured, like CT1 [CREATIVITY PHASE] (where the greatest number of ideas are to be produced), in fact require a reduced number of BCFs. In practice, the BCFs allow lucid communication while leaving the team-members free to concentrate on producing ideas. Another example concerns CT5 [PRESENTING A SPECIFIC CONTRIBUTION], where one of the participants presents a contribution that has been prepared beforehand. The central position of this participant means that the others partners really have to give their opinion on the validity of this contribution: this is why seven BCFs out of eight are necessary in order for the partners to participate fully in the COLLECTIVE TASK.

The six CTs represent the cooperative activities that the innovation project members must use to carry out the process. They are brought into play and linked according to the themes dealt with and the common aims of the

3.3 The COOPARENA Cooperation Space Model

As a result of the cognitive modeling process, we obtained a model of the cooperative activities carried out by the members of the innovation project. This cooperation space model, called COOPARENA, (see Figure 1) contains two levels: the six CTs and the BCFs which make up each of the CTs.

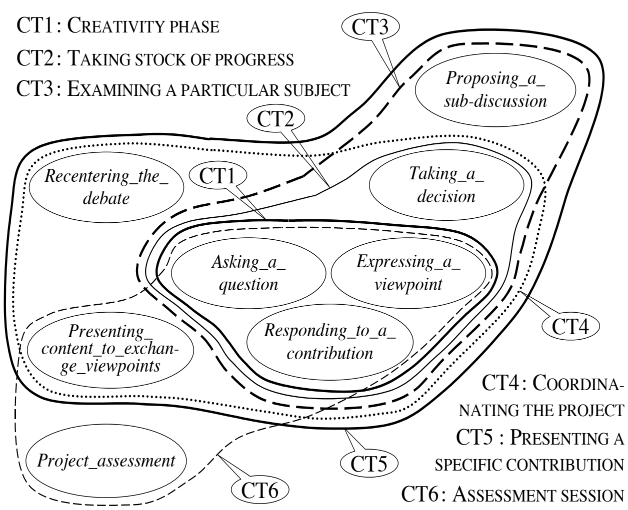

Figure 1 The cooperation space model COOPARENA: The CTs carried out during the innovation process are made up of finite subsets of *BCFs*

The six CTs represent the cooperative activities that the innovation project members must use to carry out the process. They are brought into play and linked according to the themes dealt with and the common aims of the project. Accomplishing a CT is carried out with the help of a finite number of *Basic Cooperative Functions* whose combination and order are not predefined.

4. Translating the COOPARENA model into use case diagrams

Modeling the cooperative activities was the first stage of our cognitive engineering approach. The COOPARENA model must be now translated into specifications that computer engineers can use to implement the future system. To achieve a “common language” between the human sciences and the computer science, we chose to represent COOPARENA in the form of use case diagrams, where use cases establish “a contract between the stakeholders of a system about its behavior. The use case describes the system’s behavior under various conditions as it responds to a request from one of the stakeholders, called the *primary actor*” [4, 10, 17]. Initially in text form, a use case is then completed by a graphical representation and as such, it seemed ideal for the translation of COOPARENA. The idea of using UML in the design of groupware is not new but the approaches adopted up to now have largely aimed to rationalize the groupware design process [16, 6].

Our goal here was to meet the need for a “common language” and dialogue tool between researchers in social sciences and researchers in computing, such that, once established, the cognitive model may be integrated, not as a general guide for the project, but in the form of functional specifications. Our use of UML was therefore limited to use case diagrams that meet this “translation” need. The following section reports on how the COOPARENA model served as a basis for building use case diagrams and was thereby integrated in the process of developing the collaborative platform MAGIE (Figure 2). We adopted the following semantic equivalences:

- The *BCFs* (*Basic Cooperative Functions*) were modeled in the form of use cases. They provide with textual description indicating, in particular, the actors involved, the flows of events or scenarios, and the necessary pre- and post-conditions (see [24] for an example).
- The CTs (COLLECTIVE TASKS) were modeled in the form of use case diagrams which represent all of their use cases, associated actors and their relationships. The diagrams make it possible to represent what is expected of the future system without having to specify exactly how the system meets the user’s expectations (Figure 2).

5. Discussion and conclusion

As a matter of fact, COOPARENA plays the role of a coordinative protocol which makes the innovation tasks interdependencies tractable. This coordination mechanism, as defined in [19], encompasses a set of explicit conventions and prescribed procedures of cooperation. It mediates the articulation of distributed activities so as to reduce the complexity of their articulation during the innovation process. It is a normative construct but it is embedded in the computational system in a way that allows a satisfying degree of flexibility, thanks to the unordered arrangements of the different Basic Cooperative Fonctions into the Collective Tasks. For instance, the actor will be able to combine as he/she wishes a number of basic cooperative functions (“Ask a question”, “Express a viewpoint”, etc.) to contribute to the COLLECTIVE TASK [COORDINATING THE PROJECT]. This will be supported in concrete form by current groupware functions (taking part in a forum, getting a document on-line, etc.).

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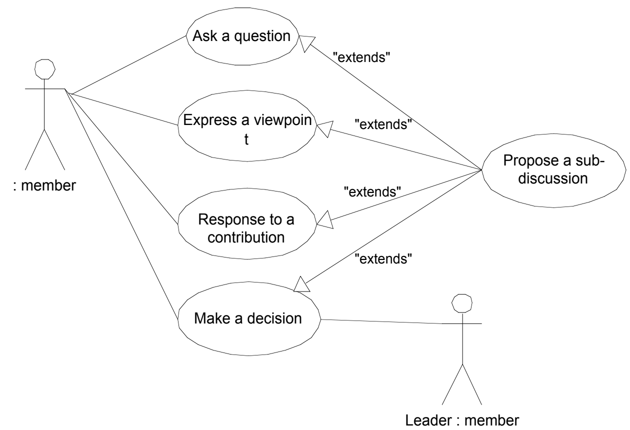

Figure 2 Use case diagram for [EXAMINING A PARTICULAR SUBJECT]

The COOPARENA cooperation space is not intended to replace all of the face-to-face meetings that an innovation project requires. As many authors [e.g. 8], we think that a Web-based collaborative system must be larger than a support to virtual meetings only. It must be seen as part of a larger collaborative work process in which synchronous and face-to-face collaboration must be preserved, recognized and supported. In this view, COOPARENA will help participants to prepare future meetings more effectively, whether the meetings are face-to-face or mediated by the platform.

The cognitive engineering approach (in the sense proposed in [9]) has led to a close association between cognitive ergonomics and computing engineers. This interdisciplinarity is not trivial: faced with differing modeling approaches (cognitive and computer science), it provides each discipline with a basis on which to build and compare its ownlogic. It also helped to go beyond simply producing a simple *description* of the cooperative activities – an all too frequent aim in studies on “usage” – in order to achieve a *technical transposition* and system specifications allowing a suitable implementation of the cooperation space in the platform.

Assessing the use of the COOPARENA cooperative space is currently underway, and consists of analyzing how the innovation project partners use the space when acting out a number of scenarios. The results will provide a performance measure of the cooperation process when it is carried out in the framework of the COOPARENA model.

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