A COOPERATIVE MODEL USING SEMANTIC WORKS DEDICATED TO ARCHITECTURAL DESIGN

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Abstract. Architectural cooperative design as well as information modelling have been active research areas for several decades. The use of systems adapted to the cooperative design assistance for the building domain is complex. This results from the complexity of the cooperative work (difficulties in tracking actor's work, lack of most of the required information, coordination problems, implicit nature of most of the construction activities, etc.) The main objective of our research in these domains is to develop a tool that helps the management of a building project and aids cooperative design. So, in the first part of this article, we propose to view the exchanging data mode and cooperation tools in the building domain. The second part of this article illustrates the existing cooperative design models. Then we justify the interest shown in a new model of cooperative design where the relational organization of the project and the semantic meaning of works are taken into account. Finally, we use this new model for defining a design-aided tool, to deduce advantages and limits of the "Virtual Cooperative Project".

1. Introduction

Research in design sciences is distributed among a great number of disciplines (human sciences, engineering sciences, etc). Design is a creative activity. It consists of the development of a project and supplying given needs with the objective of realizing a product or a building. An act of design is a designer's interaction within a group of designers. Instruments, competence and proficiency characterize this group. Points of view are often shared between contributors and decisions about different project aspects are submitted for common approbation. Every actor is a designer and brings with him his own points of view on the project. An actor's objectives, responsibilities and interests interact to contribute to the realization of the common project. If the actors must coordinate their work, it's mainly because they work on components that are in interaction and on variables that are in interdependence (Jouini and Midler, 1996).

In this context, current Computer Supported Cooperative Work tools don't sufficiently take into account the cooperative dimension and the implicit nature of building designer work (Godart, et al., 2001). These systems must help designers to obtain maximum data which allows good objectivity of the evaluation of a cooperative situation. Nevertheless, the design complexity of these systems results from the same complexity of the cooperative work (obligation to share time, tracing action difficulties, conformist attitudes, non-effective contribution, influences and dominance, overflow of data, coordination problems, etc.).

This paper will briefly review data exchanging modes on the building, as well as evaluate the cooperative design tool. It will then illustrate how the methods and models of concurrent engineering taken from the industry domain are unsuitable for the construction domain, which is characterized by a singular context of cooperation. After that we justify the interest shown in a new model of cooperative design where the relational organization of the project and the semantic meaning of works are taken into account. Finally, we use this new model for defining a design-aided tool, to deduce advantages and limits of the "Virtual Cooperative Project".

2. Cooperative design in the building domain

Design activity corresponds to a sharing of a space, which contains common and shared objects. This space is always extended by individual contribution (in cooperation) and by collective contribution (in collaboration). This co-production is structured by actors' coordination (Dillenbourg et al., 1995).

Design is an activity of reciprocal prescriptions. Criticism and negotiation represent important decision actions. Often, a great number of heterogeneous variables are taken into account to design and to construct building. Consequently, these activities are often conducted in a collective way. Actors use more and more tools to assist their work, and technologies to structure their exchanging of data.

2.1. DATA EXCHANGING MODES OF COOPERATIVE DESIGN IN THE BUILDING DOMAIN

In construction, four data exchange practices structure the cooperation approaches. The first one is a current practice. It consists of manual management of exchanges (sending disks, maps, etc.) and exchanges by electronic mail. This practice saves time, but shows a weak trace of sharing. The second one is a tested practice. It consists of exchanging data through PDM[1]. These systems are submitted to precise structuring rules of drawing up documents and have displayed their efficiency through big projects. An emergent practice is the third one, and consists of using cPDM. It's a cooperative Internet version of the PDM. These systems link electronic data management of documents and network exchange. Finally, the experimental practice which consists of sharing a digital mock-up[2] and modelling building projects by interoperable objects. This practice has not yet shown its efficiency, but is being followed with great interest (Figure1).

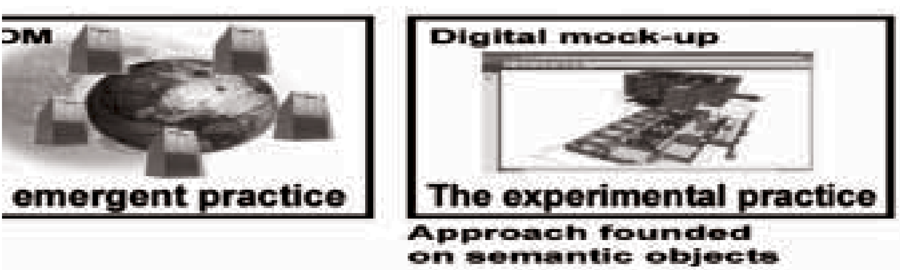

Figure 1. The different data exchanging modes.

The first three practices constitute the cooperation approach founded on documents and exchange files. The fourth practice constitutes the approach based on the use and the manipulation of the semantic meaning of a project.

At present, cooperative systems dedicated to the first three practices offer a view which takes into account the physical organization of data but does not reflect in any way the social organization of a project. Taking into account the dimension associated with an alternative structuring information mode (Dourish et al., 1999) we think this is one way to follow for the definition of a new cooperation design-aiding tool which proposes an adaptive and navigable vision of the project.

2.2. COOPERATIVE DESIGN AIDING TOOLS

Cooperative systems dedicated to Computer Supported Cooperative Work (CSCW[3]) allow the structuring of communication, data exchanges, explicit and implicit work, etc. These systems are a great assistance to project design and offer many categories of technology. These tools vary from the workflow (on the level of organization process) to the groupware or other management systems of individual activities in a collective project. Some of these systems reduce conflicts and help task coordination inside an organization. Some allow each user to deal with his own work, inform others about the state of their activities and generate automatic warning messages to regulate work progress. Other types of tools permit to edit the same object at the same moment (multi-user systems, etc.) or aid for making collective decisions (browsing tools, electronic voting, etc.).

According to each cooperative system, the three spaces of the functional core[4] are of differing importance (Salber et al., 1995). For example, the shared edition systems accentuate the production services, whereas workflow and groupware enhance the coordination and communication.

In a design project, actors cooperate to achieve a same objective, which can be the production of documents, solutions, comments, etc. These cooperative project tools do not offer each actor a good enough vision of the project development, nor help for his potential action. The cooperation context of a design project is a relational organization where each actor keeps up specific relations with other people (designers, project managers, etc.) but also with documents, activities and works. This organization has to be represented in the project design tool to give each user an adaptive vision of the project organization and development.

When cooperating, actors exchange data. However, data systems manipulate owned internal data too specialized and incompatible. Most software solutions are based on proprietary solutions with their specific technical model (Rueppel et al., 2002). It constitutes a big handicap for having a homogeneous unique referential and some “common knowledge”. The cooperative design tool should lean on the interoperability software data used by the actors. This would improve the communication capacities between software for a better quality and productivity. Cooperation activities must be based on interoperability of the software used by building actors.

According to this, we decided to provide building actors with a vision of the development of the design project in conformity with the reality. This will be possible thanks to an assistance of cooperation using not only actors, activities, documents, but also semantic works. The letters are the basis of an interoperable digital mock-up.

3. Analysis of digital mock-up model

In the cooperative approach founded on object, exchanging data in not based on documents but on their contents and more precisely on the works and the spaces that they describe. These works (walls, windows, etc.) are not defined only by graphic representations but also by their features (composition of a wall, window material, etc.).

3.1. SYSTEMS USING DIGITAL MOCK-UP

Cooperative systems of project using IFC[5] increase more and more. Most of these systems consist of an Internet platform where project exchanges are facilitated thanks to an easy access of actors. Every one following his right access has the possibility to depose and to recover documents but mainly the recent update of the digital mock-up. In the same way of a workflow approach, every user is informed by mail about a submission of a document or about an update of the digital mock-up. Some of these systems offer the trace of exchanges and the different updates of the digital mock-up (E.g., Active3d[6]).

The user navigates on web in this digital mock-up using a visualization tool integrated on the Internet platform. This common digital mock-up of IFC is built thanks to the varied actor's map (I.A.I., 2004).

3.2. THE LIMITS OF IFC DIGITAL MOCK-UP FACING THE COOPERATION ACTIVITIES

In the IFC, we found a "product model" that uses the STEP[7] norm. IAI had adopted many STEP industrial standards, but their building sector adjustment raises some data exchange problems:

- The trace of actor actions: IFC model shows tangible blanks about intervention traces and the actor role definitions in the development process of a digital mock-up. Until today, we cannot indicate whether an object has been proposed or validated by an actor (in the IFC 2.X release) (I.A.I., 2000).
- The project evolution cycle in digital mock-up: During the design of the different objects making up the project, the IFC model doesn't permit us to assign them the progression levels defining the project evolution. We cannot know if an object is under design, under modification or already validated.
- Semantic meaning used to design works: In the latter IFC update, we cannot attach to every object its manufacture constraints, its rules for setting up, etc. (Among the set of model attributes, there is no specification about regulation rules, structural characteristics, plastic qualities, etc.).

Thus, IFC model shows drawbacks relative to the cooperative dimension. This model must takes into account the flexibility of current practices and operating mode of project building: so the structure interest of all the exchanged semantic meaning relative to project works.

4. The use of semantic meaning of works to create a cooperative system

The implicit character excelling in the act of building a work implies that it is the actor and not the system who must take the initiative to carry out a coordination or regulation action of the group activities. Therefore, it's imperative to allow actors to get reliable data concerning state of the project in order to determine what the actions to be carried out are. When concentrating on the data exchanged during the project design, the works are the main focal point. In the same way, every project work holds some relation with its 'environment': with the actors who designs it, the documents that represent it and the activities that create it. Our objective is to provide actors with a vision of the development of the project in conformity with the reality.

4.1. THE COOPERATION META-MODEL AND THE MODEL OF WORK

The model definition that we propose is a continuity of Hanser's research that dealt with on a design meta-model oriented relation (Hanser, 2003). We propose a cooperation meta-model[8] that allows the taking into account of the existing relations between the elements of a project (actors, activities, documents and objects). The instantiation of the objects allows the definition of the VCP.

The Virtual Cooperative Project (VCP) is a project that we have initiated in the co-designing domain, having as a target the definition, the design and the realization of a model able to assist cooperative design in architecture.

This model is the support for the development of a cooperative system. This project rests on the use of the notion of actors, activities, and documents and of the semantic meaning of works (instantiation of objects). This research represents a new approach because it is not based on management of documents but on all data relative to works.

A work represents a physical object making up the basic brick of a digital mock-up. This object is characterized by its geometrical and topologic data but also by its semantic meanings. Every work belongs to a class, possesses attributes, relations and is set according to relative constraints. A work is the result of coordination activities given during the project and throughout the design cycle until the realization. The works have different design phases and indicate the modifications that they have incurred as being associated with the actors who use and modify them. In the Virtual Cooperative Project, the model of work is structured on 'simple work' (indivisible building work) and 'composed work' (composed of simple works).

The work's semantic meaning represents all data excluding geometrical and topologic data, and is used to define work all along its life cycle. So, in the objective of structuring an aid to the works' design, trying to group maximum data throughout their creation, we have set up a classification table of semantic meaning used to design a work (physical attributes, regulation constraints, structural properties, financial aspect, etc.). However, we distinguish five subtype classes of the 'simple work' following a professional logic taking account of the notion of design evolution during building life cycle: we design structure works first, then those of partition, of equipment, of cladding and finally accessory works. Finally, works maintain relations:

- The relationship between activities and works is distributed in time and show the works' evolution during the building's life cycle.
- The relationship between actors and works is referential and associative. It indicates actor's interventions on works. It allows us to distinguish each actor's design and reflect point of view.
- The relationship between documents and works is relative to the assignment and the data specifications.
- The relationship between works is relative to their design. We distinguish those linked to their evolution, those linked to their space organization and those linked to the nature of the relationship between physical parts.

4.2. THE DEVELOPMENT OF THE BAT'MAP SYSTEM

To manage a project 'type VCP', which generates a great quantity of information, we have used an interactive navigation interface to develop Bat'Map. This graphic interface constitutes a tool for the cooperative management of a Digital Project. Bat'Map aims at total structure of the project context using nodes and links. Different types of icons represent the fundamental concepts of a Virtual Cooperative Project (Figure 2).

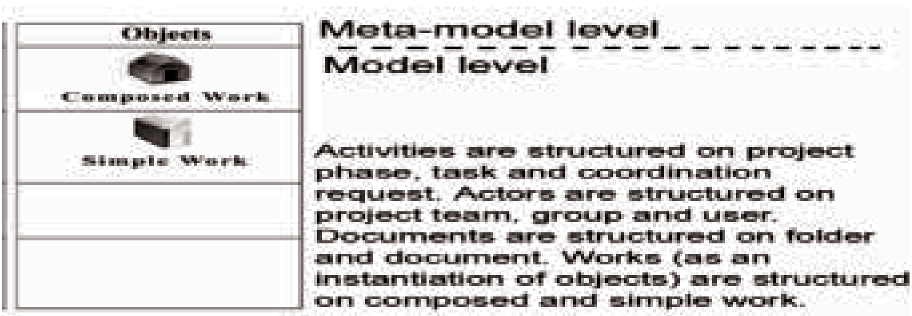

Figure 2. Icons representing concepts of cooperative activities in Bat'Map.

On the other hand, Bat'Map is a computer-based system that supports actors engaged in a goal and provides an interface to a shared environment. Bat'Map allows users to initiate a cooperative project environment by identification of actors, activities and documents. When the first update of the digital mock-up is created ('.ifc' type file), a coordinator proceeds to its download from a Bat'Group[9] web platform. The system interprets (thanks to a parser[10]) IFC's data relative to the works; visualizes digital mock-up using a "composed work" node and the works composing it using a "simple work" node. When deposing this first version of the digital mock-up (for example by the architect), the creator will have an automatic link with all works making this digital mock-up.

When updating digital mock-up, the works evolve. So to identify the new modifications, we adopt 8 states relative to the works. Every work evolves and has different states. A node state represents one work evolution context and is represented by different icons. We use colours to distinct cooperation states:

- Gray for inactive objects (proposed and not yet activated).
- Blue for active objects (in progress).
- Red when a particular attention is necessary (has problem).
- Green when the object is approved or finished.

And we use different icon forms, to distinct evolution states:

- Suppressed work: it is a work that existed in the last digital mock-up update and that is no longer reported.
- New work: it is a work that was created in the new version of the digital mock-up
- Modified work: it is a work in which we have changed at least one of its properties (thickness, height, length, material, position, etc.)
- Work without change: it is a work that was not modified.

Every digital mock-up update, the system proceeds automatically with identifying changes to works, thanks to a comparison between the ".ifc" data. Then, the system proceeds with linking works to the actor (author of the new update) as the one responsible for the suppressed, modified and new works. Works without change are linked to the last update designer, etc. These links between actors and works allow action trackability during the project design.

To facilitate navigation in Bat'Map, we have developed filters and functions allowing an adapted navigation following user needs (to show only works nodes, only actor's nodes, etc.). On the other hand, we have integrated an 'IFC 2.X Release' viewer to allow designers to visualize works. Likewise, users can specify in Bat'Map links to other software, in the objective of visualizing text documents, pictures, maps, etc.

4.3. EXPERIMENTATION OF THE SYSTEM

In the objective of validating the meta-model of cooperation as well as the model of the work, we conduct two experiments to assist cooperation design in a building project. The script adopted for the experiments describes the design of two buildings (a wooden salt store[11] and a building extension in France). Actors coordinate themselves in a distributed asynchronous mode. The script steps cover: the building evolution throughout analyzed phases, the cooperation activities solving design problems, the digital mock-up updates, the validation of phases, etc. (Figure 4).

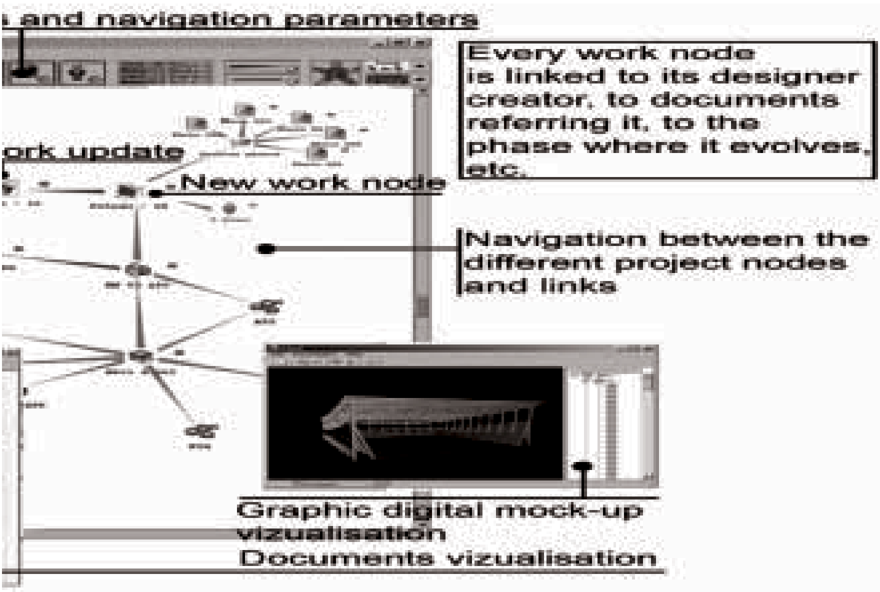

Figure 4. Visualization of the project context of the salt store with Bat'Map.

As a result of experimentations, we notice firstly that the representation of cooperation design context of a building permits a global view of the project: actors, phases, tasks, documents, works and relations between these concepts. Secondly, comparison of several digital mock-up updates during all the phases of the project allows designers to save time when they have to identify changes between updates. Bat'Map allows users to have a clearer view of the building life cycle, and to trace all actors' actions on works and documents. This constitutes a great assistance to the project management. Thirdly, semantic meaning management of works represents a design aid. The fact that designers use all the documents and data relative to a given work, allows for good objectivity in their choices, and enables them to take into account a maximum constraint. Finally, we notice however, that the current Bat'Map visualization is not suitable for use in an agency practices setting. So we have outlined how to adapt the Bat'Map system functionality to the actors' design space particularly in their CAO software.

5. Conclusion

In order to provide a cooperation system which enables the users to design buildings efficiently, and to share this system among different actors via the web for project management, this paper presents a new approach of cooperation aided-design, which proposes a new data organization of real building context, by the representation of the existing relations at same time on the site, and also inside the project. The solution of creating the environment dedicated to structuring the semantic meaning of works is the best way to satisfy our cooperative expectations. This research has allowed the definition of a model using project design semantic.

The goal of this model is to reinforce cooperation and group awareness by supplying to the actors a good vision of the project evolution in order to increase the conception quality. This will be possible thanks to an account of the digital mock-up evolution of a project and of its works during its life cycle.

Our results indicate that the identification of the different states of works allows actors to have a clearer idea of every work and digital mock-up statute. The semantic meaning thus obtained permits actors to adapt their vision of the design evolution and to avoid wrong decisions. The results of the study also show that the visualization of the different digital mock-up updates allows us to have a trace of actors' actions (author, date and modification objects), saves time in the identification of changes and allows us to specify the respective responsibilities linked to modification, creation or forgotten works.

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Notes

1. Product Data Management is a component of the technologies of data products. This concept covers the set of techniques, methods and tools aiming to communicate, on an electronic support, the product data within a company.
2. The digital mock-up is a graphic computer representation, in 3 dimensions, of project works and spaces evolving throughout a life cycle. This representation is partial and reflects a given point of view of an actor. (E.g., the digital mock-up of a climatic engineer, of a structure engineer, etc.).
3. CSCW is an initiative to understand the nature and features of cooperative work allowing design of a suitable computer technology in a cooperative system.
4. The functional core exposes the main human operations implied in a project design and these can be regrouped in three categories: communicating, producing and coordinating (Ellis and Wainer, 1994).
5. Industry Foundation Classes are currently the more successful to constitute the basic bricks of the shared digital mock-up realization in the building domain. The IFC represent a standard of exchange and sharing of data (Liebich, 2004).
6. http://www.active3d.net
7. Standard for The Exchange of Product data model: are international computer exhaustive descriptions of physical and functional features of any industrial product type during its life cycle.
8. This meta-model is described in MOF 'Meta Object Facility' (Frankel, 2003), and used to distinguish concepts, which are common to every design project practice.
9. Bat'Group is a groupware developed in our laboratory CRAI-France. Bat'Group as Bat'Map gives to each actor an adapted vision of the project context, concepts of actors, activities and documents (Halin et al., 2004).
10. We have developed a parser, which converts data relative to works contained in the IFC file (written in Express) to compatible data with Bat'Map interface (written in Java).
11. Salt store is a building used to protect salt against damp. It is employed for the bulk storage of salt. Salt is sprayed on roads against to protect frost.