User Adaptive Visualization of Cooperative Architectural Design
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A cooperative design is a social activity inside a group. In this kind of activity, each actor plays a specific role. If each actor wants to realize the actions corresponding to his role, he needs some adaptive information about the cooperation context. The cooperation context of design project is a relational organization where each actor maintains specific relations with other people (designers, project managers, etc.) but also with documents and activities. Such a cooperation context exists in architectural cooperative design which is distinguished by a “mutual prescription” between actors. In architectural design we are in a network model of actors, instead of the hierarchical model that we can find in classical workflow tools. This organization has to be represented in the project management tool to give each user an adaptive vision of the project organization and evolution. The representation and the visualization of such a network, which characterizes each project, is the main objective of the “Relational Model of Cooperation” and the hypermedia view presented in this paper.
1. Introduction

During the last decade several experimentations with groupware applications have been carried out in every industrial domain and particularly in the building trade [1]. These tools appear to be more suitable to hierarchical organizations and well-defined processes. Indeed, most experimentations have been undertaken in the construction phase or during semi-industrial construction processes with a pre-defined catalog of architectural elements [2]. In these situations, the collaboration context is characterized by well-known and repetitive processes and the processes be easily represented in workflow applications [3].

In the design phase, the cooperation is less formal with many revisions and alternative solutions. The cooperation context of an architectural cooperative design project is a relational organization where each actor maintains specific relations with other people (designers, project managers and so on) but also with documents and activities. Such a cooperation context is distinguished by a “mutual prescription” between actors. In the architectural design environments we are engaged in a network model of actors instead of a hierarchical model, of the kind we find in classical workflow tools.

The first step in our research is the definition of a cooperation model, suitable to the particular relational context [4]. The model has to represent actors, documents and activities as a relational network and not as a hierarchical structure, which is usually used in the collaborative work tools.

The second step consists of considering the context representation as a hyperdocument environment where the nodes are the project elements (actor, document, activity) and the links represent the relations existing between them. The manipulation of the hyperdocument makes the proposition of a user adaptive visualization of the project organization and evolution possible. Each actor can see all the information linked to their activity inside the project. Thus, the complexity of a project does not swamp each actor but is distributed intelligently inside the group.

In order to understand the importance of the context in an activity we present, in the first part of this paper, an activity analysis extracted from some theories of social sciences. The second part describes the context of a cooperative architectural design project that we represent using a meta-modelling architecture, and visualize in a graphical interactive view. The model and the graphical view are developed in the part three. The final part presents some experiments with the use of a prototype where the model and the view are implemented.

2. Cooperative activity: its context and tools

The development theory described by Vygotsky, who is a key player in activity theory [3], formulates the hypothesis that the subject’s action
cannot be separated from its context. The theory of the situated action [6] confirms the importance of the context in the choice of the actions of a subject. It highlights that any action depends on the material and social context in which the subject exists and evolves.

2.1. Activity structure

Activity theory proposes the concept of activity as an analysis unit of social protocols and human development. The activity preserves and describes a minimal context associated with a subject’s actions[7].

Activity theory shows the existence of three levels of abstraction that constitute an activity:

- The activity is guided by an objective: a building design is an activity for an architect.
- The actions are identified as necessary to achieve the activity objective. They reach a precise goal which corresponds to a result of a stage: drawing a plan or producing an estimate are architect actions.
- The execution of an operation within an action exists at the unconscious level. It requires an individual’s knowledge and training in the concerned domain. The operation is complete when a certain condition is verified: drawing a line or editing text using a CAD tool are architect operations.

The appropriation or the internalization by the subject of their external activity constitutes the mediation process. This consists of a mental image or artifacts which mediate the interactions that the subject undertakes with his environment to act on the object. This process is attached to the activity and to its context, i.e. “to the modes and the means which are transmitted by other people during the team work and during social relations” [7].

Engeström has clarified the process of mediation with a structural model of activity where the concepts of tool or artifact mediate the relation between the subject and the object [8]. The tool allows the subject to accomplish the object by supplementing or extending its potential of action.

2.2. Collective activity

Engeström has enhanced the structure that represents the subject activity to describe collective activities. The collective activity structure integrates new concepts such as: community, rules and division of labour (see Figure 1).

The person who takes part in an activity inside a group must respect codes and social rules specific to the community. These rules represent the artifacts which mediate the relation between subject and community. These rules are either explicit (law, standard, contracts), or implicit (social conventions, respect of the hierarchy). These two forms of rules respectively
induce two forms of coordination, explicit and implicit, within the group. These rules define the role allotted to each person who participates to an activity. They condition its potential for action. The potential for action describes all the actions that a community member can carry out on the artifacts that mediate the activity. The division of labour mediates the relation between community and object according to the explicit organization of the community that takes part in the transformation process of the object. It defines the distribution of work to the members of the community by taking into account the domain extent and the individual capacities of each activity participant.

2.3. The group awareness

The implementation of the structure and context of an activity in an assistance tool for cooperation is not immediate. The tool mediates the structure of the group and its activity. The mediation by the tool must offer an equitable information diffusion to reduce any form of resistance coming from the individual against the group. The term 'group awareness' [9] is used to indicate a favorable context for cooperation. It is characterized by the following situations [10]:

- To have the willingness to be together and to cooperate.
- To be aware of having an objective.
- To observe a progress in the way of the achievement of the objective.
- To be responsible of tasks that are necessary for the achievement of the objective.

The information generated by the group awareness must allow each member to answer questions about:

- The activity: what is its objective? What is its state? Who has to do what? Who did what? What do I have to do?
- The group: who are the members? What are their skills? Is there a hierarchy to be respected? What is each one’s role?
• The tool: who is working at the moment? How shall we inform the members? Do the other members know what I am doing?
• The object: what is its state? Can I reach it? What are the actions that I can make on it?

This list is certainly not exhaustive, but it shows the state of mind of a person who uses an assistance tool for cooperation. The information given by the tool must help users to assimilate the activity context so that they can build the operational image that will guide them in their future actions.

2.4. The existing tools

The characterization of the existing tools can be done by analyzing their space-time dimension [11] to construct a space-time matrix. But this matrix does not cover all the capacities of the existing tools. It is necessary to consider all the services provided by a tool to supplement this classification, and so we need to characterize all its functions. In this way, Ellis and Wainer [12] propose an analysis framework composed of three descriptive aspects:

• The ontological aspect defines the objects which are handled during the co-operation and the operations that can be accomplished on these objects.
• The coordination aspect defines the organization and the relations that exist between the activities of the participants.
• The interface aspect defines all the possible interactions that can be generated between the actors of the co-operation and the tool.

This tripartite decomposition has inspired the definition of a ‘functional clover’ [13] which proposes three spaces of co-operation, in which the functions can be placed (see Figure 2). The space of production allows the actors to act together on shared data. The communication space makes possible the information exchanges between actors and the space of coordination allows the actors to plan their respective activities.

![Figure 2. The functional clover](image-url)
The functions proposed in CSCW tools cover a part of these spaces according to their application domain [14]. A workflow tool will mainly cover the coordination space, while groupware (shared workspace) tool will better cover the communication space (see Figure 3).

The potential of action of any actor who uses an assistance tool of cooperation is delimited by this “functional spaces” analysis model. But theoretical approaches show that the apprehension of the context, and by consequence its visualization, is important in the choice of actions. The functions exist and work but each of them has a particular context according to the space in which it acts. The context of a co-operative activity is then diffuse and cannot be easily apprehended by a user. In order to propose a synthetic view of the context, it is necessary to represent it as a whole through a model and to associate it with a visualization which allows its comprehension.

The rest of the article will deal with the specificities of the activity context that we aim to develop. Then we will present its representation in a model and its implementation in a tool.

3. The architectural design context

The architectural domain, like other domains, represents a particular design context of cooperation. This cooperation generates cooperative interactions between actors. This situation is characterized by a “mutual prescription” between designers. Thus, each component of the project owns an environment with specific relationships. For example, an actor keeps up relations with his related documents, his activities and the other actors who participate in the same activities. The “relational model” is the representation and the characterization of these interactions in an architectural design project.
3.1. Collective activities in Architecture

In an architectural project, the interactive situations occur either in the design phase or in the construction phase. During the design phase, cooperation is less formal and produces many revisions and alternative solutions. The construction phase is characterized by an organization of actors and documents which is more hierarchical.

The differences between design and construction processes can be brought to light with a multi-dimensional graph (see Figure 4) obtained from knowledge of the construction process [15].

- **Organization**: this axis describes the social organization of the group. In a hierarchical group, one actor manages all the workgroups. In a cooperative group, the actors work together in a consensual way.
- **Document stability**: during the design phase, many document versions and research drafts are produced and continuously reconsidered. During the construction phase, the documents are more rationalized and technical; they are generated in a more linear manner.
- **Meeting style**: a design phase needs to expose many conceptual choices or ideas during “brainstorming” sessions. The construction process is based on validation steps and task assignation meetings.
- **Coordination**: explicit coordination is composed of a pre-definition of interactions between actors, e.g. planned tasks, periodic meetings, deadlines. Implicit coordination is made up of non-planned actor interactions, discussions and information exchanges [16].
- **Process precision**: in a construction process, each task is planned and its
Figure 4 expresses the fact that the design process is neither linear nor predictable. In design situations, tools like workflow engines or PDMS (Part Data Management Systems) are not appropriate to support cooperative work. These tools require actors to have a well-defined work processes and structured information, which hamper designer exchanges.

We make the assumption that the development of coordination tools for the architectural design process must, first and foremost, focus on the representation of relevant information about the project evolution.

3.2. Coordination in design

We showed in the previous section that the coordination in the early phases of a project is mainly implicit, because of the difficulty in planning the conception process precisely. Obviously, we also have some explicit coordination, such as project phases and periodic meetings, but most of the coordination actions are not planned.

The implicit coordination can be performed by the use of requests. A request is an electronic exchange which express a specific need (document validation, meeting organization and advice demand for instance). It can be associated with documents [17].

The requests are typically implicit but initiate some explicit procedures (see Figure 5). For example, a validation request asks the receiver to give an opinion in a short time. Then, the reviewing task is attached to the receiver with a clearly defined deadline. We think that request coordination is an exemplar of the cooperation in design context (flexible and user centered).
3.3. Context Description

The context of cooperative design has to represent the relations and interactions that exist between the actors, their activities and the document they produce. A context is usually composed of four elements: Actor, Activity, Document and Relation (see Figure 6):

- **Actor**: in a project, each actor has a limited capacity of action and a restricted decision-making autonomy. The actor acts inside the activities which constitutes the project, gives an opinion, keeps up relations with the environment while collaborating with other actors and producing documents.

- **Document**: a document represents a professional “deliverable” part of a contract. For example, the invitation-to-tender document will include plans, spreadsheets and texts. A document is an aggregation of files manipulated through an operating system. A document can embody several other documents. Finally, documents are generated by actors during activities.

- **Activity**: the activities inside a project have several levels of granularity: project, stage, milestone, and task. The French law on building project management defines legal stages of a project and the corresponding levels of drawing scale. The milestones separate two validation meetings inside a phase and the tasks constitute the smallest element of an activity.

- **Relation**: a relation identifies a type of links existing between two elements (see Figure 6): Actor, Activity and Document. These relations can be grouped into several categories:
  - The relations between actors and activities define the role of an actor in an activity (operational role, organisational role).
  - The relations between actors and documents are close to those used in the implementation: Supervise, Produce, Comment, Consult, Revise, Diffuse.
  - The relations between activities and documents are relative to the production of information: Generate, Use (technical requirements, rules, contracts).
  - The relations between actors find their terminology in human resources management: Manage, Contribute (provide and receive information).
  - The relations between documents are those used in the configurations management: new version of, refers to, is the synthesis of, and so on.
  - The relations between activities are relative to planning: follows, precedes, is included in, and so on.
The relation that links actors and activities constitutes a particular case because it determines the context of cooperation of each actor. This relation represents an actor’s role in a specific activity. The roles translate an actor’s implication in a project [18]. It depends on the actor’s status in the group (their responsibilities) and on his skills. The role played by an actor changes during the project lifecycle. For instance, an architect will probably be responsible for the design phase, but may be only a consultant for the building site management. A role can also be a capacity to perform actions in an activity [19]. These actions are connected to the operations on the principal components (actor, activity, document). For example, the role of the coordinator gives the following action rights:

- To plan a meeting (activity).
- To assign tasks to other actors (actor).
- To define objectives and deadlines (activity).
- To add or remove actors (activity).
- To define the documents to be produced (document).

In this context description, the relations also represent the interactions between actors that are generated during the coordination activities.

4. Model description and visualization

4.1. Relational model of cooperation

The definition of the model retains the meta-modelling approach [20] used in the standard MOF (Meta Object Facility) proposed by the OMG (Object Management Group). Our proposition consists of defining a relational cooperation meta-model which takes into account the existing relations between the elements of a project. The instantiation of this meta-model enables the definition of cooperation models dedicated to the building domain like the mastery of public work in accordance with the French law (MOP law, 1988). This architecture of modelling improves the setting of data exchanges between different models. The objective we want to reach with this type of modelling is the description of the meaning of a project and the proposition of an adapted graphical representation. Then, we propose two meta-models. The first one describes the structure of an information graph,
the second one describes the framework of a relational cooperation (see Figure 7). The instantiation of these two meta-models respectively gives a model of graph oriented to project visualization and a model of cooperation dedicated to the building domain. The definition of exchanges rules between these two models enables the proposition of a contextual visualization of a cooperative project dedicated to the building domain.

To obtain a model of cooperation dedicated to Architectural design we have to instantiate the meta-model by taking into account the French context of an architectural design project.

The French MOP law precisely defines the missions of the actors in charge of the project, according to the type of operations (such as new constructions or rehabilitation). This program prescribes five distinct and normalized stages, each cuts out in phases, which describe the progress of the project: previous studies, studies (Sketch, Summary Draft (APS), Definitive Draft (APD), the project), contract transfer, building site, operation closure [17]. In this first modelling we have tried to represent the stage of the studies where the documents, actors and activities and the relations between them are defined. The Figure 8 illustrates the instantiation of the meta-model to obtain the architectural design cooperation model. This model defines the explicit activities of a project (project, phase, task) and the potential roles (Operational, and Organizational) that can be assigned to an actor within the project.
4.2. Visualization

The search in information visualization [21] and adaptive hypermedia [22] enables us to identify new forms of information representation, more suitable to such project organization. The “relational model of cooperation” that we have proposed, considers a project as a network of information. The instantiation of this model generates a project which has an open hyperdocument structure (see Figure 9). The project organization and evolution can be viewed in this hyperdocument. Each node is an element of the project information (document, activity, and actor) and the links are the relations that exist between each project component (such as produce, manage and use).

In this kind of visualization, it is important to determine the quantity of information and the number of the different types of information. People are not used to handling this type of representation (see Figure 9), so the network complexity has to be gradually discovered by the user. In order to reduce the apparent complexity of the representation, the graphic uses specific representations of the model concepts with a variety of forms, colors and sizes. Actor, Activity and Document are represented with different and adapted icon representations; the color is used to indicate the state of an object (Activity: not started, in progress, finished, in conflict). The form, the color, and the length of a link must give an indication of the type of relation it represents (role of an actor, reference between documents, task sequence).
According to the complexity of such a graph (see Figure 9), the hyperdocument visualization must be accompanied with some navigation function.

4.3. Navigation

The navigation tools present a set of functions to allow the user to manage the graph. An incremental navigation is possible, it can be structured in clusters [21] following the activity/sub-activity structure or document folder/document structure or actor group/actor structure (the navigation is then close to those present in a hierarchy) or by node expansion (the linked elements are drawn where the node is selected). Some filters are useful to select, inside the graph, the pertinent information to be viewed. The filters must allow the user to choose among the types of nodes and links to characterize the information as desired. For example, an actor who wants to know the actors with whom that actor will work and in which activity, has to select actor nodes and activity nodes and rejects the document nodes.
4.4. User-adaptive Navigation

Each actor within the project is a potential user of the cooperative platform. In the relational model of the cooperation of the project, each actor owns a profile that describes the associated competencies and trade activities. In addition, all the roles that the actor plays in the activities of the project are known. By taking into account this set of information (profile and role, attached to each actor/user), we can propose an adaptive navigation to be applied to each user. The actor’s profile gives information on the user: the type of documents that user can visualize, the type of project view that user can apprehend (Gantt view, 2D or 3D view, version graph of documents...), and other information such as the type of computer equipment that this particular actor has. The role played by each actor in project activities allows the system to define the nodes and links to display and the precision level to take on each node. For example, a supervisor of an activity may not have the same representation of the activity node representation that a simple reader has. The supervisor can navigate inside the sub-activities and can access to the different versions of the activity documents, whereas a reader has only the possibility to see the activity node and the related document nodes. The user can see the state of documents indicated by the color of the node; but can access and visualize a document only when it is finished. A user-adaptive view may allow a user to evaluate all the tasks that have to be accomplished inside one project or for all the projects managed by the cooperation platform.

5. REALISATION AND EXPERIMENTATION

5.1. The Bat’Group Prototype

In order to be used by all potential actors of a cooperative project such as those existing in a building design project, the cooperative platform we have developed was located on a multi-level web client/server architecture realized with J2EE tools. This architecture respects the MVC Smalltalk paradigm [23] where the view role is held by the TG LinkBrowser Java applet (www.touchgraph.com). The hyperdocument object plays the control...
role (JSP and servlet) and the model role is represented by objects (Java beans) which instantiates the relational cooperation model presented in the paper. The object persistence is managed by a relational DBMS system (see Figure 11).

Two types of interface have been implemented: a classic one, Bat'Classic, with a hierarchical files browsing and a graphical one, Bat'Map, which proposes the contextual view presented in the article. These two forms of user-interfaces have allowed us to achieve comparative experiences in the framework of architectural design projects.

5.2. Experimentation

A first experimentation made in an architecture office demonstrates that the relation model of cooperation and the graphical visualization presented here can be used to represent a real cooperative project and can be used also to manage negotiations. An completed real project has been entered in our prototype platform to allow us to undertake the analysis. All the interactions have been analyzed in details and implemented in the system to evaluate the capacity of our model to represent the real world equivalent. Then, we asked the project architects to manipulate the contextual project view to show and examine some specific points relating to the project. After a short period of adaptation, all the architects who participated to this project were able to achieve such a task.

The application of the tool within a real framework of project remains difficult, due to the fraught economic and time-constrained context that the building sector knows all too well. In this situation, we have undertaken a validation with a scenario. We wrote a project scenario which has been validated by a group of experts from the building project domain. Then we put in scene this scenario in an experimental context composed of student actors using the Bat'Group platform. A group, the traditional group, had to play out the scenario with the traditional interface, and another group, the
graphical group, used the graphical interface. This experiment, which was described using illustrated diagrams showing sequence (see Figure 12) in [14], allowed us to measure the impact of a contextual visualization within a simulated co-operative framework. The actor-students in the graphic group carried out the scenario more quickly than the traditional group which, typically, had difficulty in finding in the traditional interface, either the function to be used, or the exact place where to put information. The context visualization and the dynamic creation of nodes and links, available in the graphic interface, proved to enhance efficiency compared to a hierarchical visualization of information.

6. CONCLUSION

We have proposed a new organization of information closer to the real context of the building design that uses the representation of the relations existing within the cooperation context. The relations that we identify allow an adaptive navigation inside the projects according to an actor’s roles and relations. The concepts expressed in the article are those of a meta-model, which we propose as an alternative to the traditional models of co-operation presented in current tools. The objective of the meta-model is the definition of an organization of information (the cooperation model) that enables a relevant visualization of a co-operative project context by taking into account (by instantiation) the requirements of a precise branch of industry. The sector concerned here is that of the architecture and AEC.
Bat’ Group prototype implements the model and proposes a graph visualization of the context of co-operation. This tool has allowed us, through two experiments, to make the model upgrade, and to propose a set of adapted functions of visualization and navigation. These experiments have partly validated the fact that a contextual visualization allows a group to work on a design project more effectively.

Our longer-term objective is the extension of this meta-model by integrating the component “products” defined in standard IFC of the IAI, in order to propose a model of co-operation around the numerical mock-up [24].

References


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