Assistance to coordination in the AEC sector

A multi-view interface dedicated to building construction activity

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Abstract: In the Architecture Engineering and Construction (AEC) sector, cooperation between actors is essential for projects success. During the building construction activity, organization is both hierarchical and adhocratic. Decision assistance tools have to integrate these heterogeneous parameters. The proposition described here consists of the design of a coordination assistance tool providing synthetic indicators on the statement of the activity and also allowing the user to navigate in the cooperative context through multiple views. This proposition is based on a model architecture allowing us to manage cooperative context information and its visualization.

1. INTRODUCTION

Collective activity management and decision assistance are main research and application areas in different domains (enterprise, industry etc.). Potentialities of new tools based on IT lead to design and use of decision information systems.

These new tools are adapted to and engender change process in work methods and sometimes in the organization structure itself.

In this study, we focus specifically on cooperation between actors during the building construction stage. Should a decision information system, as we briefly described it before, increase quality of interaction between actors? And if so, should it increase quality of process management in AEC? We will try to answer this question in this article.

First we will present methods of decision assistance identified in different organizational contexts. We will analyse also the importance of human-machine interaction in interface design (HCI) and the place of final user in computer system design.

Then we will try to identify the types of organization of actors on building construction sites and the existing coordination modes associated with them.

This theoretical approach will allow us to present our proposition to assist coordination between actors during building construction. We will describe the system infrastructure that we are setting up at present to develop this assistance tool. In particular we will describe the model approach characterising this proposition. Finally we will come back to building construction activity by presenting a use scenario of our tool, the first validation step of this study.

2. DECISION ASSISTANCE IN ORGANIZATIONS

2.1 Organizations typologies

Studies by Henry Mintzberg appear especially interesting when it comes to distinguishing between organization forms (Mintzberg 1979). In order to try to summarize his approach we suggest contrasting "traditional" organization (bureaucratic) with new forms of organizations called "adhocratic".

Traditional organization is based on methods and process standardization. However this model shows its limits when organization becomes more complex and dynamic.

"Adhocracy" concept introduced by Toffler (Toffler 1970) describes perfectly the contemporary context of change management, work method development, competitiveness etc. This concept also covers a more "democratic" vision of collective work. Thus decisions should be distributed between actors and personal strategies should be preserved.

2.2 Methods of decision assistance

This brief overview of organization typologies studied in the early 70s helps us to approach contemporary methods of decision assistance. In fact in these different types, organization and activity are managed by one or more actors and by the way of different methods and tools.

We retain two major ways of thinking to assist decision making and management: the performance management and the development of awareness processes. These two approaches are fundamentally different but appear as complementary to us.

2.2.1 Performance indicators and dashboards

In the early XXth century, the "classical" firm is managed on the Ford/Taylor model. Henri Fayol (Fayol 1918) describes this model according to five main management principles: planning, organising, ordering, coordinating and control. This "classical" model of the firm is in contrast with the contemporary "reactive firm" model (Fernandez 2005). According to Alain Fernandez it is in this context that "new dashboards" have to be designed: more precise piloting and reactivity with permanent improvement in mind. Moreover in these organizational changes the decision process should be approached in a cooperative framework. Each actor should have their own dashboard comprising adapted information for their decisional needs.

The dashboard is then a decision assistance tool. It allows the user to understand a situation and it formalises possible choices. We can note that it is applicable in organization forms where information is highly explicit and available in information systems.

2.2.2 Awareness in a distributed management context

In an "adhocratic" organizational context characterised by ephemeral teams and mutual adjustment between actors, group awareness by the actors is very important. It favours informal and unanticipated activities (Gutwin 1997). For Lucy Suchman « actions are often socially and physically situated and situation is essential for action interpretation" (Suchman 1987). Then awareness is also necessary for adaptation of the activities to the changes in the project (Bardram 1997). Carl Gutwin distinguishes between 4 awareness categories: informal awareness, social awareness, group structure awareness and workspace awareness. Numerous research works focused on methods to clarify awareness in groupware.

We retain especially here the 3 levels of awareness process defined by Mica Endsley (Endsley 2000). 1) The perception of relevant elements in the environment, 2) the comprehension of these elements and 3) the prediction of the state of these elements in a near future.

This process interests us particularly here. In fact awareness plays a major role in coordination mechanisms in the informal and ephemeral organizations.

2.3 Human-machine relationship in decision tools design

The relationship between the user of such a system and the machine is fundamental for success of the tool use. In different research domains such as computer science, artificial intelligence and HCI we have retained two major fields which appear essential for systems design:

– Works on context-aware applications in mobile computing or in artificial intelligence (Brézillon 2002; Dockhorn Costa 2003) show that the user and his context have to be placed at the centre of tool design in order to better answer his needs. For (Dey and Abowd 1999) a context-aware system “uses context to transmit adapted and relevant information to the user”. Research in mobile computing in AEC (Löfgren 2005) shows the importance of adapting information representation to the hardware tools used: their capacities and to the situations of usage. Moreover the user should be able to intervene in the software he uses, e.g. in bringing his personal expertise to adapt the tool to his application domain (cf. works on application malleability (Bourguin 2000; Koch and Teege 1999)).

– Interface design adapted to the user’s needs at a precise time is the second research field that interests us. Works on ecological interface design (Vicente and Rasmussen 1992) suggest guidelines for HCI design related to the type of events the user has to manage: “familiar”, “unfamiliar but anticipated” and “unfamiliar and unanticipated”. Ecological interfaces are based on SRK taxonomy (Skill, Rules and Knowledge) by J. Rasmussen which models information treatment carried out by humans (Rasmussen 1986). This taxonomy is a guide for displaying information in a way adapted to the cognitive and perceptive faculties of humans.

3. COORDINATION IN THE AEC SECTOR

We have described above two approaches which are essential in the decision assistance domain and their applications in decision information systems realisation. But should these approaches be used in the AEC field? We will try to answer to this question in this chapter.

3.1 A cooperative context complex

The AEC sector is an industrial field which is distinguished from others by some particularities. Teams’ composition is ephemeral and heterogeneous. The building as a product has to face many constraints such as functional, technical, economical, esthetical constraints varying from one project to another. Time development of a project is sequential.

The organization in construction projects takes different forms (Cf. §2.1). The “bureaucratic” and hierarchical model is identified in a general way. However in design and construction stages “adhocracy” appears perfectly adapted to the reality of the relationships between actors. In fact implicit grouping of actors for realizing a task or activity is current in this domain.

3.2 Coordination modes related to this context

These different organizations identified in the AEC sector engender particular coordinative practices. We distinguish between “multi-actor” and “inter-actor” coordination.

“Multi-actor” coordination aims to organise activity and to inform the entire group of what is happening in the project. It describes the explicit activities. Its objectives are to define the conditions of building construction activities and to allow a “strict” and realistic survey of progress.

“Inter-actor” coordination can be defined as peer-to-peer coordination. It consists generally of implicit and informal activities (Kraut, Fish et al. 1990) from an actor to another one. It allows the actors to work together, adapting their actions to the action of other actors and to the project development. This type of coordination, at the “actor level”, can get around problems generated by the complexity and slowness of “multi-actor” coordination.

Our study focuses on the building construction activity. At this stage “multi-actor” coordination is essentially based on artefacts (Schmidt and Simone 1996) i.e. meeting reports, and on planning activities (Bardram 1997). “Inter-actor” coordination consists of informal meetings or discussions between two actors in an “adhocratic” organization (Beiarsto 1997), i.e. mutual adjustment (Mintzberg 1979). It often takes an oral communication form (Andersen, Cartensen et al. 2000).

4. A “CONTEXTUAL MULTI-VIEW INTERFACE” FOR DECISION ASSISTANCE DURING BUILDING CONSTRUCTION

Our proposition consists of a context multi-view representation tool. Based on “dashboard tool concepts” the role of such a tool is to allow one or many actor(s) involved in an activity to follow and monitor the progress of this activity and to measure its performance (Fernandez 2005). But this proposition goes beyond the traditional design of dashboards.

In fact we think that every actor in the building construction operation should be involved in their task coordination. For example in an inter-actor coordination case, each actor should find relevant indicators related to the activity and should be able to navigate through the project context to better understand the situation. This is a kind of democratic vision of coordination in building construction operations.

To develop this project we have looked into awareness theories (Endsley 1995; Greenberg and Gutwin 1996; Gutwin 1997). M. R. Endsley’s work underlines the different resources of awareness used by actors implied in a collective activity: perception of the relevant elements of the environment, understanding of these elements, and prediction of their state in a “near future”.

Based on awareness theories we suggest defining functions for the building construction multi-view interface (Figure 1):

– **Context perception**:

The multi-view interface presents information in a way adapted to the user (his role, his needs etc.). Numerous visualisation modes allow the actor to be aware of their environment and to perceive the progress in the activity. Linking these views gives a highest level of perception of the context to the user. Indicators should highlight essential points (i.e. risks) in a synthetic way. We distinguish between two types of indicators: relationship indicators and synthesis indicators.

Relationship indicators are the result of a specific treatment determining which concepts in a view are linked to another view. In fact “near concepts” of the project context should have different names in each model view. Our global cooperation meta-model (part 5.1) is the key to linking these concepts. Relationship indicators allow us to highlight concepts in the multi-view panel and to select information during navigation.

Synthesis indicators are closer to classical dashboard indicators. Analysis of process dynamics compared to its previsional progress (planning) lets us determine critical points in the activity. A specific “dashboard view” will be developed comprising indicators adapted to this type of information (green-orange-red lights, speedometer-like views etc.).

– **Comprehension**:

In a multi-view interface, information visualisation has to be synthetic (i.e. filtered, adapted). The user should navigate in the project context in order to better understand information provided by relationship and synthesis indicators. Relationships between concepts and views are a way to explore different aspects of the context. For example, selecting an element in a view enables the user to interact with related views by transparent requests in a database. This allows the system to display a new multi-view arrangement and information content adapted to the user selection.

Moreover to explore precisely a problem, the user should have to use a specific, adapted software tool. That’s why we suggest links towards usual tools in the interface. These links open destination tools and pass on navigation-context to them (e.g. an element selected in views). Available tools should also allow the sending of a contextual request to an actor (e.g. sending a mail).

– **Anticipation**:

The user should anticipate himself the future state of the process, based on his understanding through multi-view and indicators of the dashboard. But if the process is modelled a dashboard should also monitor its progress and warn the actors of risks.

Figures 7 and 8 show hypothesis of interface design for the multi-view tool. At present, we suggest four different “type of visualisation modes” (used in other tools) for the multi-view window: Gantt planning view, 3D mock-up, text and graph. A “dashboard view” comprising specific indicators is under development.

These visualisation modes are arranged specifically to the user context. During navigation user should change of view manually. Arrangements are also pre-determined for specific coordination tasks.

A red colour highlights important points of the activity in order to link information concerning a specific coordination point in the different views (i.e. task delay in the planning, its explanation in the meeting report, and its 3D representation in red in the mock-up).

A toolbar is placed at the bottom of the window. This toolbar will allow the user to switch to a specific tool, i.e. to start a planning tool to have a complete visualisation of the planning.

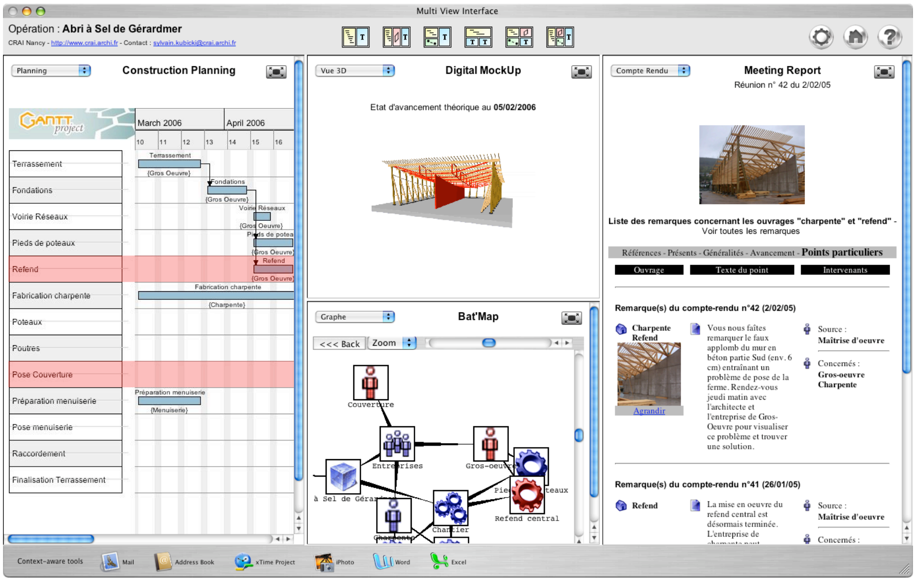

Figure 1: Hypothesis of the multi-view interface

5. STRUCTURING INFORMATION AND MANAGING VISUALIZATION: AN APPROACH DRIVEN BY MODELS

5.1 A cooperative context meta-model

The definition of a meta-model allows us to highlight essential abstract concepts to describe context of cooperation in different domains. These "meta-concepts" of the meta-model (*M2 level*) will be instantiated in specific cooperation models (*M1 level*): building construction activity context model, project management model or in other domains such as software engineering. The meta-modelling approach (Sprinkle, Ledeczi et al. 1999) is used in the standard MOF (Meta Object Facility) and is proposed by the OMG (Object Management Group) in the Model-Driven Architecture (MDA) framework (Bézivin and Gerbé 2001).

Our proposition consists of defining a relational cooperation meta-model that takes into account the *existing relations between the elements of a project*. The objective we want to reach with this type of modelling is the description of the meaning of a project and then the proposition of adapted tools and visualization modes included in a cooperation platform (Halin, Hanser et al. 2003).

5.1.1 Relational meta-model of cooperation for design and construction

To model the activity in a building construction project we suggest an approach from the point of view of cooperative activities between actors. Modelling these concepts of cooperation will allow us to develop domain-specific applications (Hanser, Halin et al. 2002) structured on the base of the *cooperation meta-model for design and realisation*.

The context of cooperative design and construction activities has to represent relations and interactions between the actors, their activities, the artefacts they produce and the tools they use:

Activity (M2): the activities inside a project have several “scale” levels: project, phase, and task. They should be explicit (building task) or implicit (request between 2 actors).

Actor (M2): in a project, each actor has a limited capacity of action and restricted decision-making autonomy. The actor acts inside the activities that constitute the project, gives an opinion, and keeps up a relationship with the environment while collaborating with other actors and producing documents.

Artefact (M2): The generic concept of artefact describes any piece of information or other “thing” manipulated, used or produced by actors in an activity (Kruchten 1999). It could be a document which represents a professional « deliverable » part of a contract. A document is an aggregation of files manipulated through an operating system. A document can group several other documents. It could be also a “model” of the object to design. In this way, the realisation of the object is the goal of the cooperation project. An object could comprise other objects (group of objects). In AEC a model could be a digital mock-up.

Tool (M2): Tools are a kind of resource needed to run a process. Their availability for a user could be defined in his operational role in an activity. For example, an architect involved in a design activity needs mock-up and CAD tools. He doesn’t need planning tool at this time. Tools use one or several visualization modes. These visualization modes are defined by models which describe the element that the interface should display.

Relationship (M2): a relationship identifies a type of link existing between two elements (or concepts described above):

– The relationships between actors depends on the social organization of the group (hierarchical or adhocratic relationships),
– The relationships between actors and artefacts are close to those used in the edition of documents: Supervise, Produce, Comment…
– The relationships between artefacts (documents or models) are those used in the configuration management: new version of, refers to, is the synthesis of,
– In a general way the relationships between tools and other entities of the model describe what information they should visualize and manage…
– The relationships between tools and actors allow defining which tool should be use by an actor (related to his role, his skill),
– The relationships between tools and activities describe how tools should be associated to specific activities, which they may completely or partly automate,
– The relationships between tools and artefacts are relative to the function of the tool: what artefact it should produce or manage. Some tools are exclusively dedicated to the visualization of information.

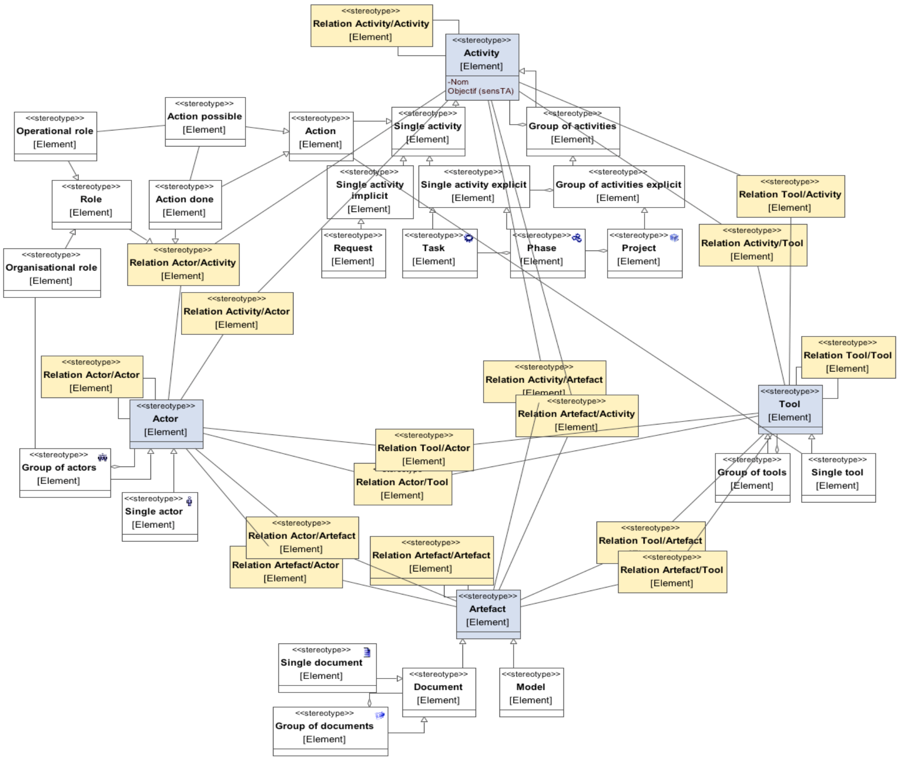

Figure 2. Meta model of the cooperative context

Information regarding the context of the collaborative project can be represented and described by this meta-model.

In the framework of the development of a new tool, the meta-model will allow us to structure the information exchanged in the cooperative project and to control the management of this information (visualization, exchange).

This meta-model describing cooperative context is generic. We will use it to instantiate a specific model dedicated to the AEC domain and especially to the building construction activity.

Figure 3 shows an example of instantiation of this model architecture. We can see some entities of a cooperative context (M0) described by meta-entities of the building construction dedicated model (M1). This model M1 is itself an instance of the meta-model of cooperative activity (M2) presented in detail in Figure 2.

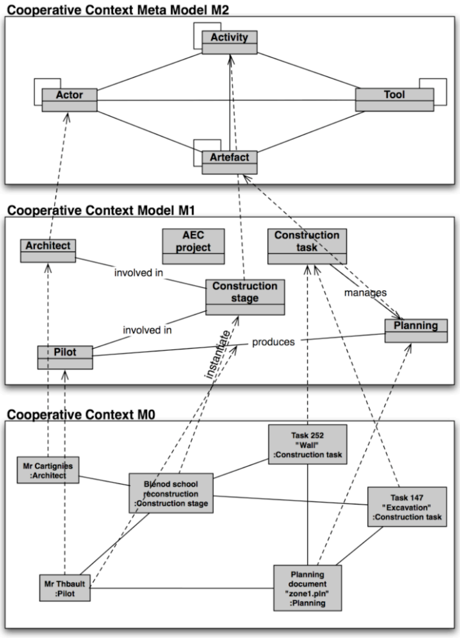

Figure 3. Example of instantiation of the 3 levels of the architecture

5.1.2 *BoardGet* models and meta-models

The model architecture presented above is essential for structuring information. It allows us to manage it in a database and to adapt information displayed to the users of tools.

We are working now on the links existing between this cooperative context and the tools allowing the visualization of this content. The multi-view interface suggested here (part 4) uses several visualization modes (called *BoardGets*) to display the content to the user. When the selection of this information is done in the database, we then focus on displaying it in visualization modes.

To do this, each *BoardGet* has to be described by a model. By using the same model architecture described above, we obtain a meta-model (M2) of the BoardGet, its model (M1) (describing the elements of the graphical interface) and finally its instantiation in a real interface M0.

Figure 4 shows an example of instantiation M1/M0 in the case of Bat'Map application. In the bottom right hand part there is a view of the final interface displayed. On the left, there are the levels M1 and M0 of the context model transformed into M0 and M1 models of the BoardGet.

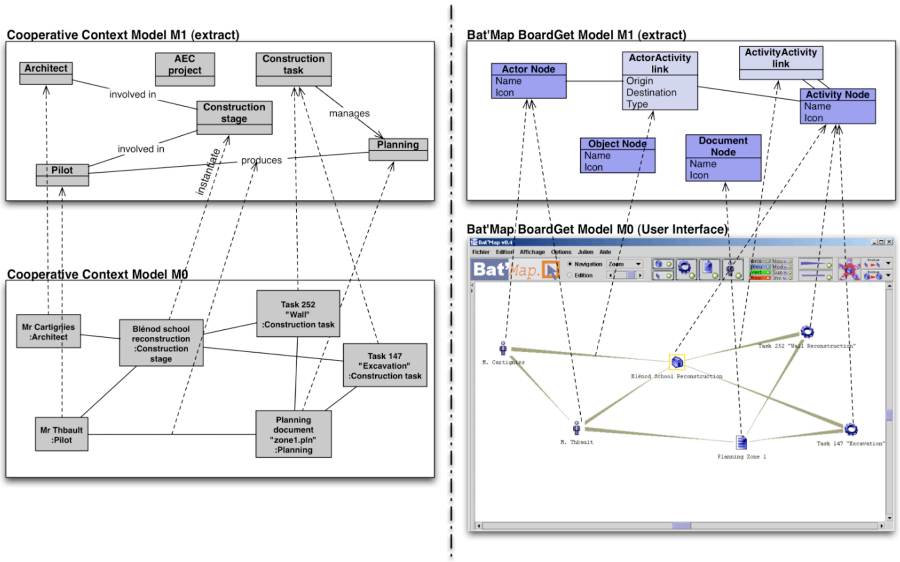

Figure 4. BoardGet interface, its model (right) and cooperative context (left).

5.2 Model transformation rules to build visualization BoardGets

Transformations are described also in the MDA architecture from the MOF. To do this cooperative context and its visualization mode are considered as models (see Figure 5). A transformation is also a model defined by a meta-model conform to the MDA model transformation standard: MOF QVT.

In this architecture each model (input or output) has its meta-model which is used to define the transformation model. Thus the transformation model describes the form of rules to execute in order to describe the transformation from the input model to the output model.

The Atlas Transformation Language (Bézivin and Gerbé 2001) will be used to specify the transformations. ATL is a transformation language for MDA and is able to translate EMF[1] models (http://www.eclipse.org/gmt/) using both declarative and imperative constructs. The transformations are described as a set of transformation rules and the ATL virtual machine uses these rules to generate an output model from a given input model.

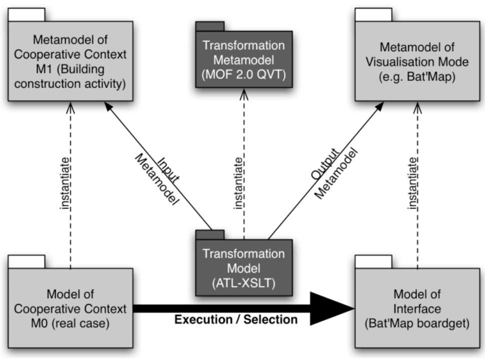

Figure 5: Transformation architecture

Transformations between models will allow us to present information in a specific view (building interface) and also to make links between views (i.e. highlighting a task in the planning and its corresponding remark in the meeting report).

6. CONCLUSION

The research work on this project is still in progress. For the moment we have chosen an approach with scenarios in order to evaluate the relevance of this proposition. Scenarios demonstrate the advantages of using a coordination tool favouring awareness. It does not really allow us to validate interest of a multi-view interface tool. The development of a demonstrative prototype is in progress in order to demonstrate the interest of project multi-visualization in an awareness tool.

This article presents a study about coordination of actors during the building construction activities. Organization types and coordination modes identified lead us to the original proposition of an assistance tool for decision assistance. To favour awareness we suggest a multi-visualization of the project context allowing the user to navigate through information. This proposition is also based on the design of indicators to represent the statement of activities (this part of the study is still in progress).

[1] Eclipse Modeling Framework (EMF) is a modeling framework and code generation facility for building tools and other applications based on a structured data model

This tool provides assistance to informal coordination forms, such as mutual adjustment. It is designed through the particular point of view on the building construction activity as an activity where decision is distributed relatively to skill or responsibilities of each one.

The software development suggested is integrated in a general approach based on cooperative context modelling. This modelling allows essentially the sharing of this cooperative context and its user-adaptive representation. Moreover we suggest also modelling visualization modes to develop information visualization tools (BoardGets and multi-view arrangement). We are working at present on model transformations to visualize the context in a BoardGet. The tool is still in development stage (architecture setup, BoardGets definition).

We have begun also a validation phase of this proposition, by the use of scenario that we will discuss with professionals. A prototype of the tool will help us in this enquiry stage.

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