

# Multi-visualization of the Cooperative Context in Building Construction Activity

## A Model-Based Approach to design AEC-specific Visualization Interfaces

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### Abstract

*Cooperation between actors in design and construction activities in architecture is an essential stake nowadays. In professional practices the actors involved in construction projects use numerous tools. The project is unique but the “views” that actors manipulate are various and sometimes fundamentally different. Their common characteristic is that they partially represent the cooperation context through a “business specific” point of view. Bat’iViews suggests to the actors a multi-view interface of the context and enables to navigate through the different views. This proposition is based on a model-driven approach. We distinguish between “context modelling” and modelling of concepts represented in each “business-view”. A model integrative infrastructure allows us to develop the prototype and to manage user interaction through the definition of models’ transformations.*

**Keywords---** Building construction, Coordination tools, Human-Computer Interface, Multi-visualization, Model-Driven Engineering.

## 1. Introduction

The AEC<sup>1</sup> sector regroups actors involved in specific actions all along the building life cycle. In design and construction activities the teams of actors are ephemeral. Then it is difficult for them to have durable relations. Moreover professional entities involved are heterogeneous and their business logics, their operational modes, their objectives and their constraints are relative to the business characteristics or to the type of firms.

Coordination management is then an essential stake in project success. It has to be flexible to favor personal initiatives of each partners of a project. Each one uses specific tools supporting his needs and his business practices. The views of activity existing in the different

software solutions used represent only partially the cooperation context of a project. We suggest here an innovative tool, which present these views to the user in an integrated interface.

Then the actors of building construction will have contextual information that actual tools do not provide. Each one of these views has its own representation model. Convergence in a unique HCI and conceptual links between views could only been realized through a larger infrastructure, based on a model encompassing cooperation context in its wholeness.

We will describe here the modelling of cooperation context, the modelling of the concepts represented in the views and finally their integration. This one enables the *Bat’iViews* interface construction and the management of its navigation functionalities.

## 2. Cooperation context in architectural projects

### 2.1 Organization of actors

In AEC projects, construction stage is extremely important because it groups numerous and independent actors during short periods. Their activities are low predictable and they very often have to adapt their tasks and decisions to the specific problems they encountered. Organization of actors takes different forms in this evolving context. It is *hierarchical* when an actor is responsible of the work of the others (i.e. building construction coordinator). We call it *adhocratic* when actors are grouped in an informal way to solve a specific problem, punctual and unanticipated.

### 2.2 Coordination of activities and document-support

Coordination of activities depends on these organization forms. In hierarchical organization, a coordinator monitor tasks progress, anticipate problems and organize their solving. His work is based on specific

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<sup>1</sup> AEC, Architecture Engineering and Construction sector

artefacts helping him to diffuse coordination information, such as construction planning and meeting report.

In adhocratic organization, coordination is essentially informal. It is an essential coordination mode during building construction activity. It ensures adaptability of the actions to the unpredictability of the activity and to frequent changes. In this coordination form, documents given by hierarchy don't serve directly the actions of the actors. They provide contextual information that actors need to adapt their decisions.

## 2.3 IT-based tools to assist coordination

Some IT tools support coordination needs in AEC, i.e. planning tools and meeting report writing and diffusion tools. They automate some coordination tasks, and their interfaces (HCI) are similar to the paper documents that they replace. Tools combining multiple views on activity appear progressively. This is the case of 4D CAD [1] which offers a 3D representation of building elements linked with temporal execution of the planning (3D+time).

These tools need explicit modelling of tasks, of elements to build and of the actors-resources. Thus they are essentially designed for coordinators and used in hierarchical forms of the organization.

It doesn't exist many tools supporting mutual adjustment between actors in adhocratic organization forms. Our hypothesis is that mutual adjustment could be increased by tools and interfaces helping the actors to better understand the context of their actions.

## 2.4 Synthesis

Cooperation in AEC projects involves many entities: actors realize activities, produce documents and use tools. Coordination is an essential stake of cooperation during building construction. The adhocratic organization is particularly visible and it lets us consider the flexibility of coordination as a very important aspect of projects' success. The tools to develop have to integrate this aspect and to favor contextual perception. We distinguish between the context itself (described above) and the views representing it and used in tools.

## 3. A model-based infrastructure to design AEC-specific visualization interfaces

To answer these needs, our method consists to define and put in relation models. We inspire for that about the field of research of the Model Driven Engineering.

### 3.1 Model Driven Engineering: a unifying approach

Our approach is based on model development, steering both domain analysis and tool engineering. This method is largely inspired by existing methods in the software engineering domain.

Since 2000 the Object Management Group has developed an approach called Model Driven Architecture (MDA) for software systems development [2]. Their objective is to define a framework of certified industrial standards (MOF, UML).

In parallel, the Model Driven Engineering (MDE) research area is an evolution aiming to unify different technical spaces (XML, ontology etc.). It does not focus on a unique technology: it is an integrative approach [3]. Concretely MDE recommends the use of *meta-models* to define *domain languages*. *Models represent real systems*. Each model has to be *conformed to* its meta-model [4]. Finally the *transformation* concept is a central one. It allows the models to be productive. A transformation is itself described with a model.

The field of the MDE research is now extended to the design of Human Computer Interface [5, 6]. Researchers involved in diverse approaches of the HCI's design find a federative framework in the MDE approach and envisage new transversalities of their works.

We identify number of models linked to HCI (Model of task, of domain, of navigation, of needs, etc.) [7]. In an integrated engineering, the relations between these models can be described and supported by tools to improve the plasticity of interfaces[6] (i.e. adaptation of the user's context).

Our approach finds its origin in this field of research. The developments that we will describe in the next parts take into account two types of models:

- Models representing concepts of the AEC domain,
- And models describing concepts represented in each view exploited by a tool.

### 3.2 Modelling the "cooperation context" in AEC

We use this methodological framework and propose two levels of modelling for the cooperative activity in the AEC domain. Firstly, a meta-model of the cooperation context allows us to describe the cooperative activity at a high level of abstraction. This meta-model is used to construct a specific model representing the particular context in an operation of construction. MOF architecture, which we base this reasoning on, integrates perfectly in the approach with models and meta-models of MDE. This particular work is more precisely described in [8].

Our relational cooperation meta-model takes into account the *existing relations between the elements of a project*. We identify four main elements existing in every cooperation project: activity, actor, artefact and tool.

A model - focusing on the specific building construction activity - has been developed. It represents the specific context of construction: realization tasks, involved actors (i.e. firms and facilities), tools used (i.e. planning tools) or documents (i.e. meeting report). For example, it allows us to manage explicitly the relationships existing between two documents: a remark in the meeting report concerns a task in the construction planning.

### 3.3 Modelling AEC-specific views

The development of new interfaces to be integrated into cooperation assistance tools has to take into account the existence and the specificity of “business-views”. These “views” of the cooperation context are those that professionals manipulate in their daily work.

So, we propose to model the “views” such as they are used in the tools supporting cooperation, which are existing and/or emergent. We precise that the model of visualized concepts defines only the semantic content of a view, turning down technical dimensions, model of navigation, model of tasks and other specific models for HCI. Then, a view can be represented with three abstraction levels like the levels of modelling of the cooperation context. At the bottom, we find the view itself, i.e. the user interface operated in a tool (e.g. a view of the execution planning).

Thus, its model represents the concepts that the interface uses. These concepts are specific for the profession that uses the view. In our example, the view planning represents the “resources” (firms), the tasks, their temporal links, and it is a view generally used by the coordinator.

Finally, the meta-model of the view “planning” is the one of UML.

### 3.4 Proposition of a model-integration infrastructure

Our method is based on two types of models: model of the cooperation context (part 3.2) and model of concepts represented in views (part 3.3). Our needs relative to the use of these models are the following ones:

- To define specific and adapted tools for the construction domain such as they are described in the cooperation context model,
- To establish a methodology to represent views adapted to the AEC domain, notably to design new innovative interfaces,
- Finally, to link views conceptually, i.e. to describe relations between concepts in complementary views. For example, a task in the view “planning” can be associated to one (or more) remark(s) in the view “meeting report”. This semantic link can only be expressed according to the specific knowledge of the domain described in the cooperation context.

The integration of these models is translated in an infrastructure which we will use like a methodological guide to develop the interface Bat’iViews (cf. §4).

The figure 1 represents graphically this infrastructure. At the centre of the pyramid, we find the levels of modelling of the cooperation context. That is

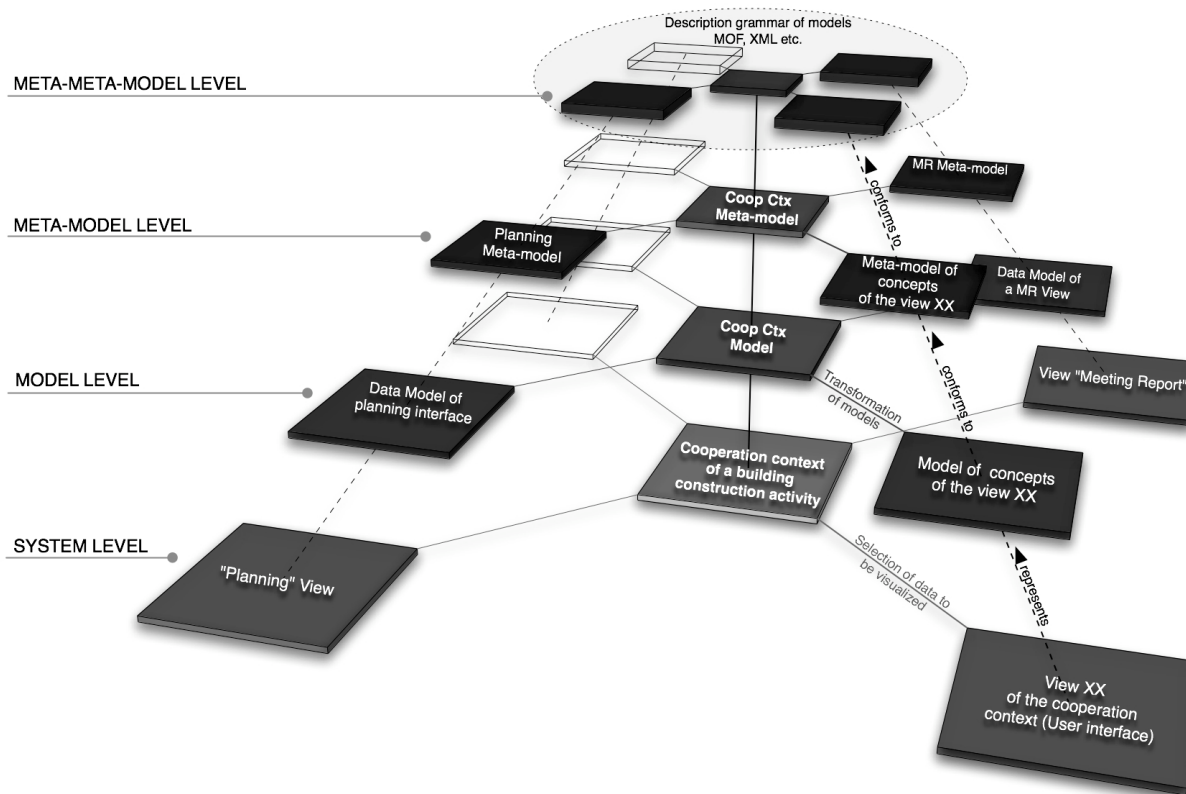


Figure 1: Model integration infrastructure

the “knowledge of the construction domain”. All around we find the models of views of the context implemented in tools. Structured on the same principle, we find the view (HCI), its model and its meta-model. To construct a particular view, it is necessary to operate a transformation of models to extract the concept from the cooperation context to be represented in the view (“Transformation of models” in the pyramid). At the lowest level, to construct the visualization interface with data coming from the context of a project, the transformation is established in reality like a transformation and a selection of relevant information in the context for the construction of view. This operation of selection is performed in function of what the view can really displayed (depending on the model of concepts of the view), but also, in function of other criteria that can be taken into account like the context of the actor using the view (e.g. his role, his right of visibility on information, etc...).

Prospecting the development of cooperation context multi-visualization interfaces, the unification of models proposed by this infrastructure is necessary to homogenize relationships between views. So, the

cooperation context model gives to the views the global semantics (relationships in the cooperation context) in which their concepts are integrated.

#### 4. *Bat’iViews* : A multi-view interface dedicated to building construction activity

We said that it doesn’t really exist tools favouring mutual adjustment in adhocratic organization forms. At the opposite, numerous tools, as planning and meeting report tools support hierarchical coordination.

##### 4.1 Context multi-visualization benefits

In the adhocratic organization form of building construction we consider the cooperation context as complex information set and its comprehension by the actors is quite difficult. In fact, the tools only give a partial and fragmented representation of the context: geometric (plans), three-dimensional (3D mock-up), temporal (planning), etc.

We think that if the conceptual links between these documents (and views) were more explicit, the actors

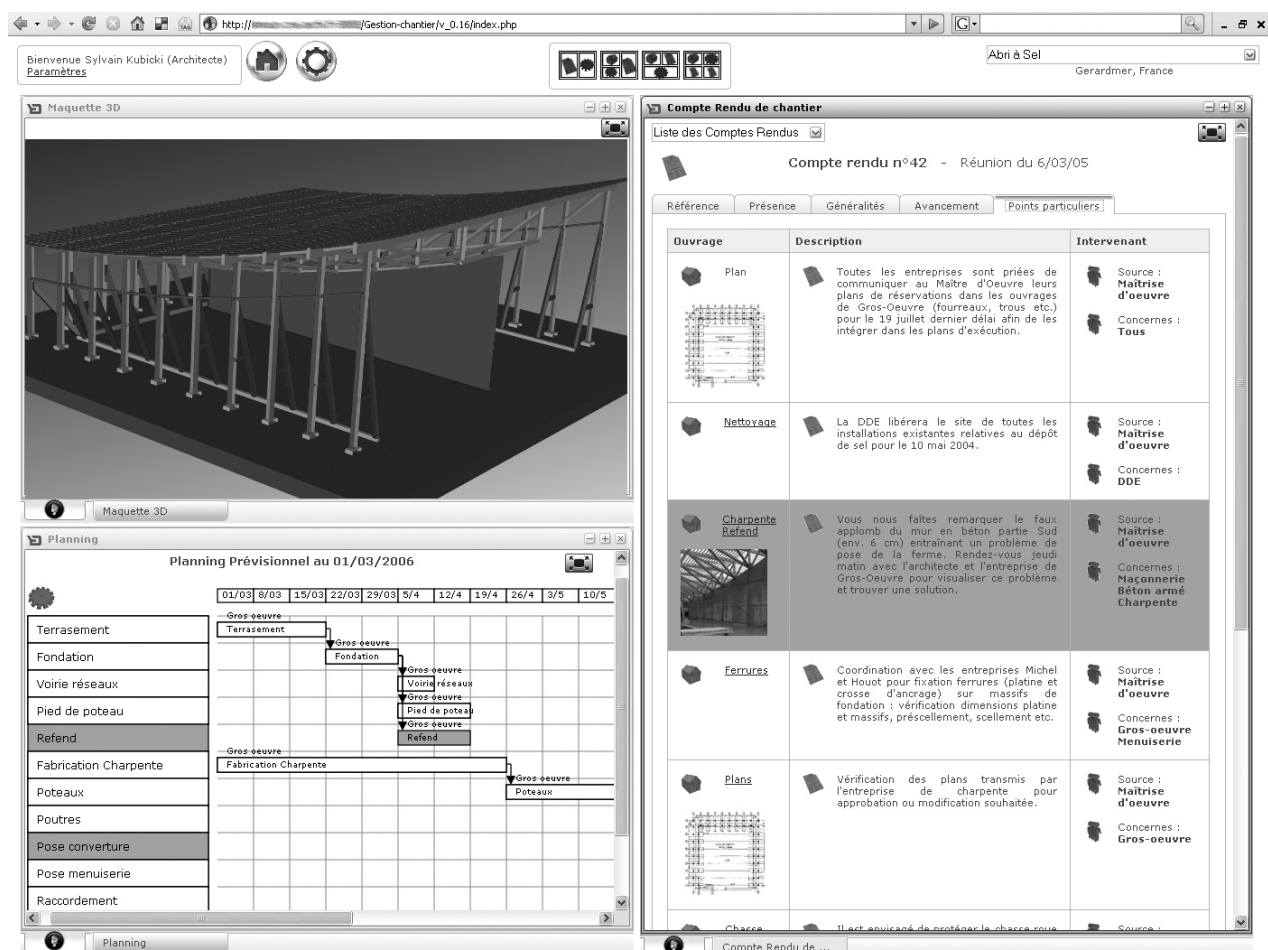


Figure 2: “Bat’iViews”, a multi-view interface prototype

could have a better comprehension of their actions' context. For example a task in the planning could be referenced in a remark of the meeting report. Then we suggest an interface representing these links and enabling the navigation in the context.

Our approach is largely based on the research area of complex informational set visualization. We found that multi-visualization of an informational set through multiple points of views enable to reduce its complexity [9]. Numerous research works focus on coordination of the multi-views interfaces (HCI), both in terms of ergonomics and techniques [10, 11].

A Human-Machine Interface offering multiple views of the cooperation context of an AEC project will help the actors to better perceive the context, favouring their comprehension of the relations existing between the different views that they use.

## 4.2 Bat'iViews prototype

Section 2 of this article shows that information related to coordination (the cooperation context useful to

the building construction actors) is represented in numerous views attached to documents, coordination tools or communication tools. To improve context comprehension by the actors, it is necessary to provide a representation, adapted to the user, showing relations existing between the different elements of the context.

Bat'iViews (figure 2) suggests to make use of views manipulated everyday by the construction stakeholders and to integrate them in a navigation tool showing relations existing between content elements of each one. The interface integrates 2, 3 or 4 views, highlights relations between their concepts and enables interaction based on the concepts represented in each view.

Thus, this proposition reinforces two fundamental characteristics of building construction coordination:

- Favouring coordination understanding by the actors, and then improving coordination quality in hierarchical forms of the organization,
- Improving awareness through automatically highlighting relationships between concepts in each view. Moreover these concepts enable

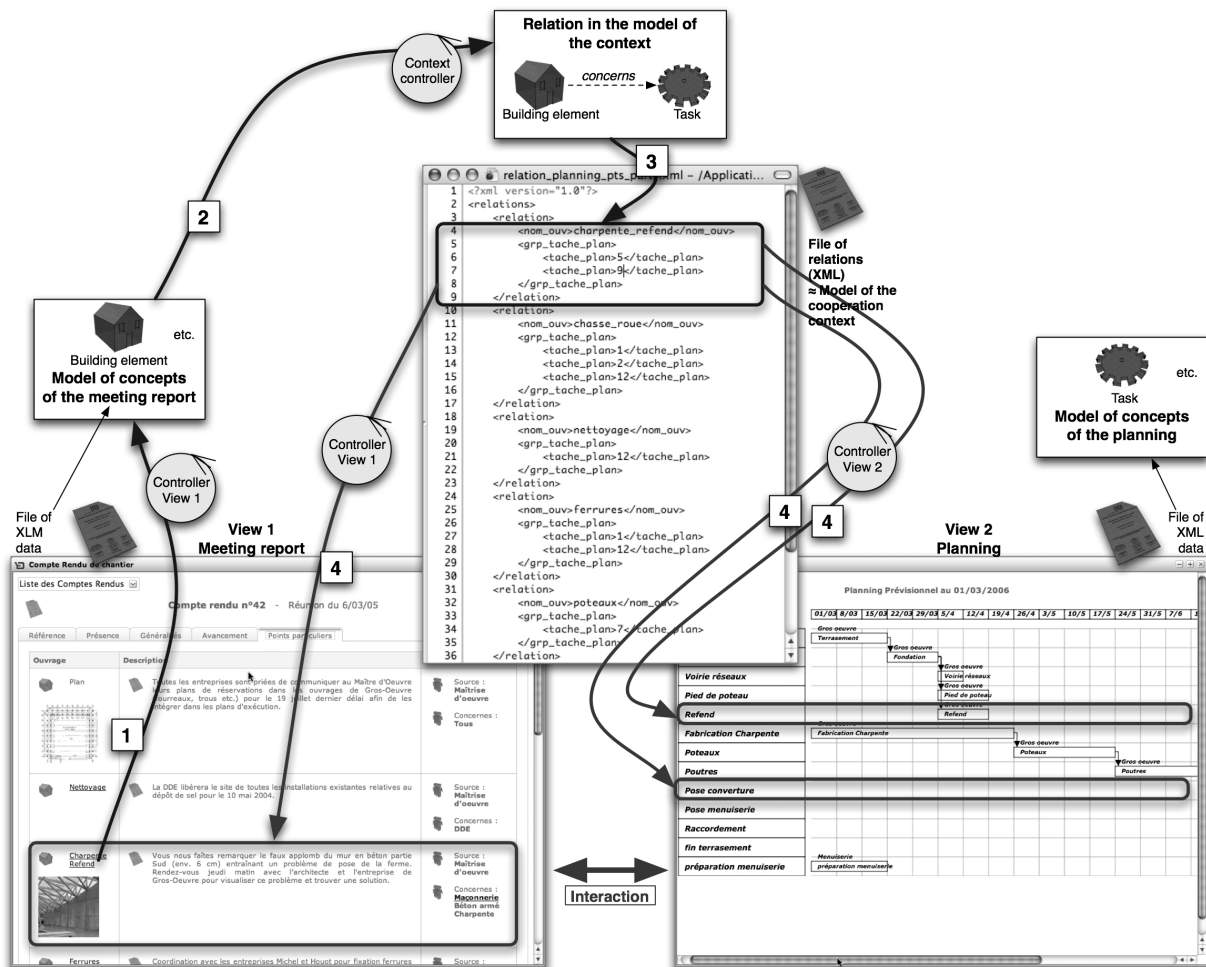


Figure 3: Bat'iViews interaction principle

user-interaction and navigation in the cooperation context.

We think that this contextual knowledge of the collective activity could help the actors during mutual adjustment situations (adhocratic organizations). They could work more precisely, estimate the consequences of their actions, and reducing risks due to misunderstanding of the work of the others.

### 4.3 Validation

Generation of the content of each view needs requires a model transformation. This transformation enables to build the concepts represented in a view from the concepts existing in the cooperation context. It is defined at the “model level”, from the cooperation context model to the specific model of concepts of a view. At the lowest level (interface) the execution of the transformation consists also in a selection of the relevant concepts to visualize, relative to the view’s model and to the user context. The management of interactions between views is based on MVC paradigm and on models transformations. Each view has its own controller and data (model). It exists a general controller, which coordinates the views and executes the transformations to extract data from the cooperation context. This principle, used in *Bat’iViews* prototype, is described in the figure 3.

This functional validation of our infrastructure has to be completed with a business validation, still in progress. At present we have essentially developed theoretical cooperation scenarios to validate our hypotheses [8].

### Conclusion

The building construction activity, its coordination and its monitoring is supported by a lot of tools, interfaces and models used fragmentally by a set of independent actors. We propose here a multi-visualization of the context based on a models infrastructure. Our goal is to improve cooperation context understanding by the actors, and so, to favour the mutual adjustment characterizing the adhocracy. The *Bat’iViews* prototype suggests to construction actors multiple “business views” arrangements that are now already independently manipulated.

The modelling of the cooperation context aims to represent relationships existing between different entities involved in the building construction activity monitoring. It also provides business semantics to develop new tools. The modelling of the concepts represented in the views allows us to describe their visualization capacity, i.e. the specific nature of information that they provide to their users.

The suggested infrastructure regroups these models in order to make them productive, to generate interfaces adapted to the context of use, and also, to manage the navigation in the *Bat’iViews* prototype, putting in relation the concepts related in each view.

A second version of *Bat’iViews* is currently in progress. It aims to use the MOF QVT technology recommended by the OMF to specify and realize models transformations. The transformations will be described as rules using ATL (Atlas Transformation Language)<sup>2</sup> and its implementation in an Eclipse platform. The virtual machine of ATL will allow us to implement their transformations as Web services accessible by the AJAX client of *Bat’iViews*. Moreover, we consider also extending this approach to other models used in the design of HCI. The tasks models will allow us, for example, to work on the user-navigation between different views.

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