A Multi-View Cooperative Platform for Building Construction

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Abstract. Building construction is a complex activity, involving numerous and heterogeneous actors during relatively short periods. The methods of project management used are specific because of the complexity of the architectural "object" and the prototype character of each operation. Methods usually used in industrial sectors (such as workflow definition or inverse engineering) are not transposable in the AEC domain. In fact, coordination modes existing in this domain are adapted to his particularities (decentralised decisions, uncertainties on the building construction methods etc.). We suggest to model this particular cooperative activity using a driven model engineering based on the MOF architecture. This form of engineering allows us to define entities in relation in the cooperation at a high abstraction level. Then this abstraction leads us to design tools adapted to the cooperation in the AEC sector by defining an infrastructure based on a cooperation model. We will suggest a new assistance tool for coordination (multi-view cooperative platform) taking into account the analyses of coordination modes and the experiment of IT potentialities. It proposes an information representation adapted to the user context and viewed in an adequate visualization mode.

1 Introduction

An AEC[1] operation is characterised on the one hand by the particularities of the architectural object (situated object, prototype object) and on the other the specificities of the cooperative practices (variable teams, decentralisation of decision). The building construction stage contrasts the necessary cooperation for progress and success of a project with the internal strategies of numerous actors involved in the operation, and particularly the contractors.

Our hypothesis is that final product quality (or building quality) depends highly on the quality of cooperation between actors during the project: interactions, exchanges, and communication. Cooperation during this stage consists essentially of the coordination of the independent actors' teams, which don't have a global "vision" of the

[1] AEC : Architecture Engineering Construction

project context. Their "vision" is very often limited to their contract: tasks and works to build.

The objective of our approach is to offer to each actor a good vision of the project through the design of new assistance tools. This approach is inter-disciplinary. We look at this subject from the point of view of the analyses of existent work practices in the construction area. At the same time, we are interested in research domains such as social sciences, human-machine interface, mobile and ubiquitous computing, model driven engineering etc. These fields of research develop interesting methods that we could transpose to our needs in the AEC domain.

We describe in this article the model approach on which we base our developments, and especially the meta-model of cooperation developed in the CRAI laboratory through different research works. Then, we show how the model approach allows us to develop a specification for the information structure of a new coordination tool. Finally, we propose a multi-view cooperative platform and the global infrastructure in which it will be defined. This platform includes also a building construction dashboard tool adapted to the user-context.

2 Tools and methods to assist cooperation

Complexity of AEC projects and associated cooperative practices lead to particular coordination modes. This production system appears today as well balanced. But we have noticed that there are some dysfunctions which reduce global quality of cooperative activities and then of the architectural object itself: information overload, unlinked information, difficulty in tracing events, risk of redundancy and contradiction between documents, lack of coherence or sometimes absence of information.

New methods and new tools have been developed for some years in order to take into account these limits of coordination. They have been developed to assist the design stage, construction stage or both.

2.1 Present and emerging practices

"Digital plans servers" are used for important project to facilitate document exchange. "Project management servers" allow the users to organize and manage different activities [1] such as requests between actors, tasks etc. Other collaborative tools try to associate planning and information exchange. The interoperability of tools used by different actors is at the basis of many research works. It becomes a reality in some CAD tools. This is possible by the use of exchange data formats, which are "object" oriented, such as the IFC format[2]. We have seen too the development of the use of digital photography. This media appears to be interesting for its qualities of context representation and understanding [2]. But these new methods remain quite unusable for every-day work. They come from other activity sectors such as manufacturing

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[2] IFC format is a data format for construction oriented « object ». http://www.iai-international.org

industry and are not well-adapted to the AEC context and its particularities: changes in the project, uncertainties, adaptation, informal coordination…

2.2 Research work analyses in Information Technology

Our approach to designing new assistance tools for cooperative engineering is interdisciplinary. Research areas such as social science, artificial intelligence, software engineering (mobile computing, model driven engineering) and information systems (groupware) are sources of theoretical analyses and innovating methods that can be applied, sometimes partly, to cooperative engineering in AEC.

Works on context aware applications in mobile computing or in artificial intelligence [3, 4] 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 [5] a context aware system "uses context to transmit adapted and relevant information to the user".

Research in mobile computing in AEC [6] shows the importance of adapting information representation to the hardware tools used: their capacities and to the situations of usage. 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 [7, 8]).

Human-machine interface is a primordial factor for the use and the impact of a new tool. Ecological interfaces described by [9] give a conceptual framework for interface design. Definition of an abstraction hierarchy allows system designer to describe the domain, and the SRK taxonomy (Skill, Rules and Knowledge) allows us to identify what type of indicator is adapted to the interaction situations.

Our approach to the AEC domain and to cooperation assistance is based on works from model-driven software engineering [10]. Firstly the MOF structure [11] gives us a conceptual framework to represent collective activity and relations between collaborative entities. Beyond knowledge representation, research in model-driven visualization [12] allows us to imagine how to link cooperation information on a project with its visualization in tools.

Thus the context modelling that we will present in the next part should be associated with representation models and visualization models [13].

3 Modelling cooperative activities in AEC projects

Representing the complexity and the particularities of the domain is the first step towards propositions for new assistance tools for cooperation. A cooperative project context comprises different elements in relationships. We will now describe an "abstraction" method to model this context.

3.1 Meta-model approach and objectives

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, meeting-report model, project management model or in other domains such as software engineering.

The meta-modelling approach described by (Sprinkle et al. 1999) is used in the standard MOF (Meta Object Facility, Figure 1) and is proposed by the OMG (Object Management Group).

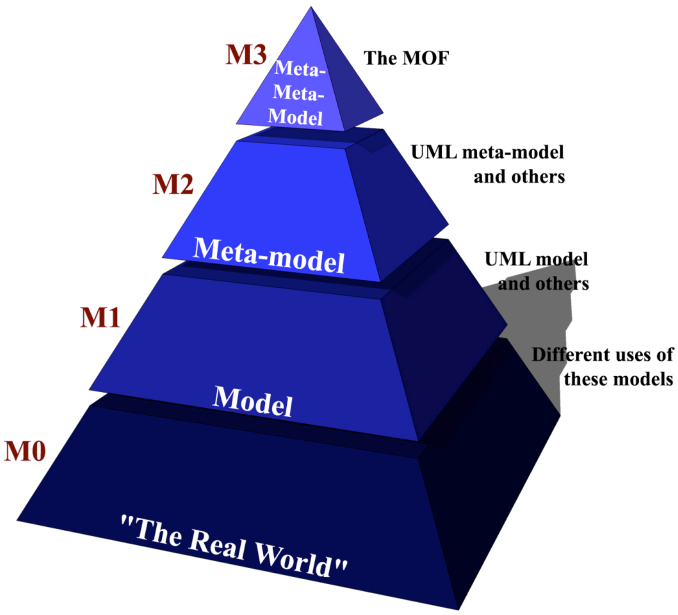

Fig. 1. MOF architecture

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 [14].

3.2 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 (i.e. exchanges or dependencies). Modelling these concepts of cooperation will allow us to develop domain-specific applications [15] structured on the base of the cooperation meta-model for design and realization (Figure 2).

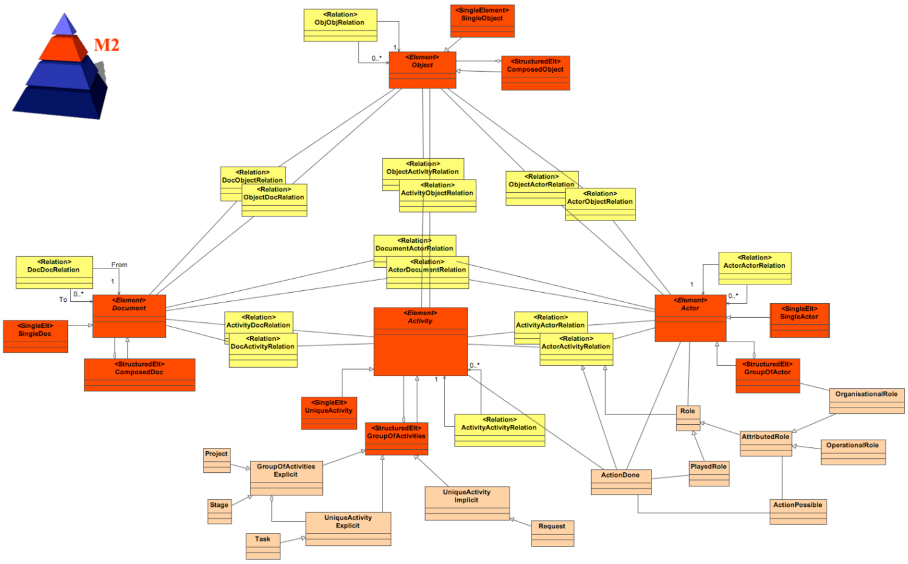

Fig. 2. Cooperation meta-model

The context of cooperative design and construction activities has to represent relations and interactions between the actors, their activities, the documents they produce and the object of the cooperation:

- 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. An actor often works in a group.
- Document (M2): a document 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. Finally, documents are generated by actors during activities.
- Object (M2): The realization of the object is the goal of the cooperation project. An object could comprise other objects (group of objects).
- Relationship (M2): a relationship identifies a type of link existing between two elements:
  - The relationship between actors depends on the social organisation of the group (hierarchical or cooperative relationships),
  - The relationships between actors and activities define the role of an actor in an activity (operational role, organisational role),

– The relationships between actors and documents are close to those used in the edition: 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 relationships between actors and objects depend both on the role and the activity: drawing, calculating, building,

– The relations between documents are those used in the configuration management: new version of, refers to, is the synthesis of,

– The relations between documents (graphical, textual or table) and objects are essentially: describes, references, explains,

– The relationships between activities are relative to planning: following, preceding, being included in, and so on.

3.2.1 Cooperative activity model (M1) in the AEC domain

Our interest focuses on the use of this meta-model in the AEC domain. Entities described at level M2 should be instantiated in domain-specific models, and particularly in construction activity. For example, in Figure 3 the class "actor" of our meta-model should be instantiated at the model level as "architect" or "pilot" which are types of actors in the AEC domain. The "object" of the meta-model should be instantiated in our domain in "works" and "spaces". A "document" should be a "planning"… In part 4 we will present an example of instantiation of the meta-model in the building construction coordination around the meeting report document.

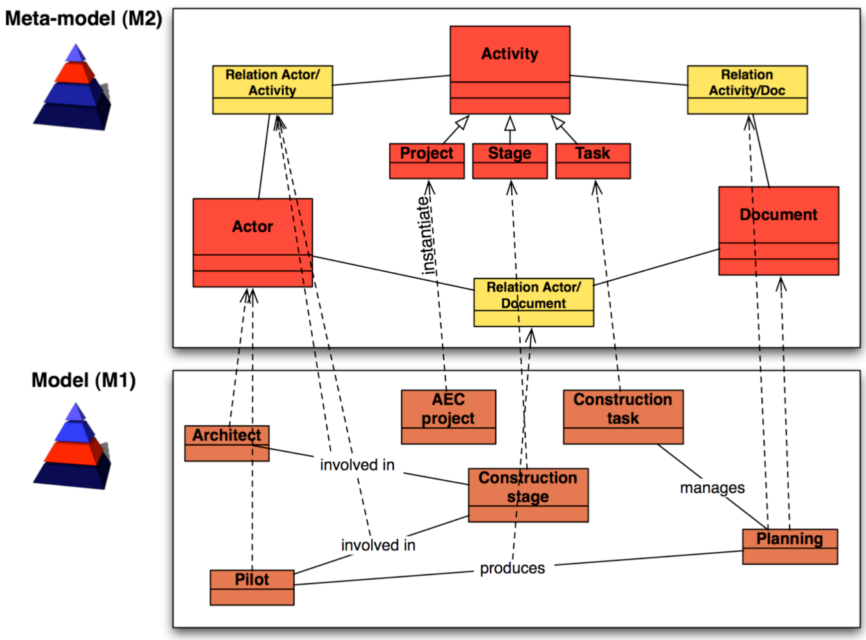

Fig. 3. An example of instantiation M2 - M1

3.2.2 Instantiation example: "Real" context of a project

Finally this model architecture allows us to describe the real situation of a cooperative project in the AEC domain (example in Figure 4). Context information (actors, activities, documents, objects and their relations) should be managed in a project database, developed using M1 level structure. In this case the advantage of the meta-model approach is to structure information in a way relevant to the domain concerned. Moreover the user should be able to intervene in the M1 structure, in order to modify the tool properties (malleability).

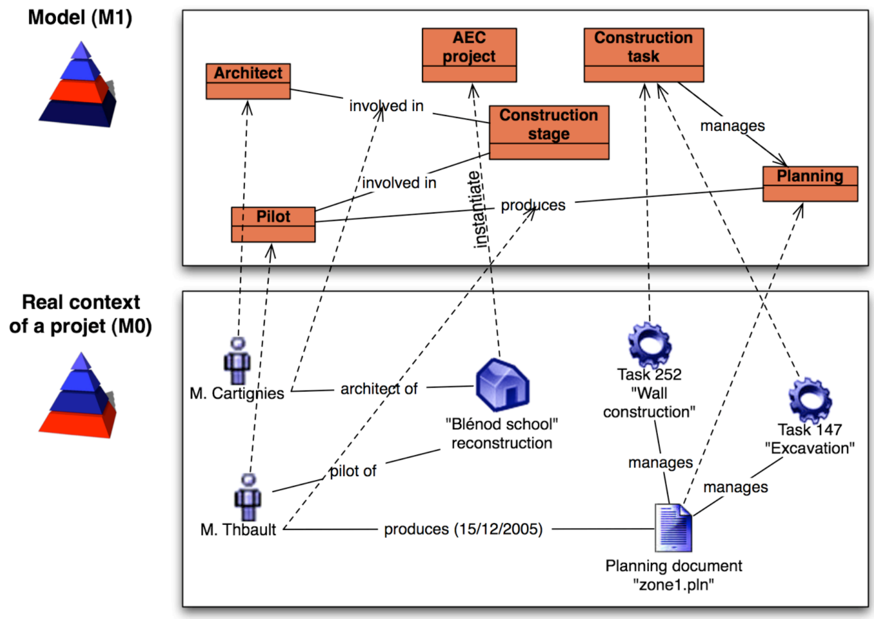

Fig. 4. An example of a real project instantiation

4 A Multi-view cooperative platform

Coordination information covers a wide domain. It comprises information on interactions, regulation and information on the designed project itself. Numerous tools and documents are therefore necessary to coordination.

Our proposition consists of a multi-view cooperative platform dedicated to building construction. This platform includes and is managed with a specific and modulating dashboard. 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 [16].

4.1 A building construction dashboard

Moreover as we conclude in the above part, it seems to be essential to suggest a tool which shares coordination information and presents it to the actors.
With this focus, we have been interested in awareness theories [17, 18]. 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,
- Prediction of their state in a "near future",
- Beginning, if necessary, of regulation operations.

Based on these theories we suggest defining functions for the building construction dashboard:

- Context perception: It consists in allowing the user to visualize coordination information using content-adapted representations (text, graphs, 3D mock-up). Information it-self has to be adapted to the user (his role, his needs…). With the focus of measuring performance, indicators have to be chosen in order to alert the user of problems happening during process progress (e.g. delay on a task),
- Comprehension: Information it-self is not enough. The user should be able to access to a level of comprehension of information, in order to understand the project's state. That's why the dashboard will be connected to other tools adapted to the comprehension of problems. The switch will be "context-aware": the user will be positioned in the right place in the new tool (e.g. in the planning tool: on the task concerned by the indicator in the dashboard),
- Anticipation: The user should anticipate himself the future state of the process, based on indicators of the dashboard… But if the process is modelled the dashboard should monitor its progress and warn semi-automatically the actors of risks and problems.

Figure 5 shows hypothesis of interface design for the dashboard. At present, we suggest three different visualization modes in the window, used in other tools (Gantt view, 3D mock-up, text and graph). These visualization modes are arranged on the dashboard specifically to the user context.

On the top of the figure, the dashboard is dedicated to the architect of the project. The representation focuses on 3D visualization, which is relatively common and comprehensible for an architect.

On the bottom, the dashboard is dedicated to the pilot. This actor is more interested by schedule information, and organisation information. That's why we suggest a graph view at the centre of the window. BatMap hypergraph [14] is a project carried out in the CRAI laboratory. It displays project information in a graphical way, focusing on links between actors, documents, activities and objects.

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 dashboard window. This toolbar will allow the user to switch of tool, i.e. to start a planning tool to have a complete visualization of the planning.

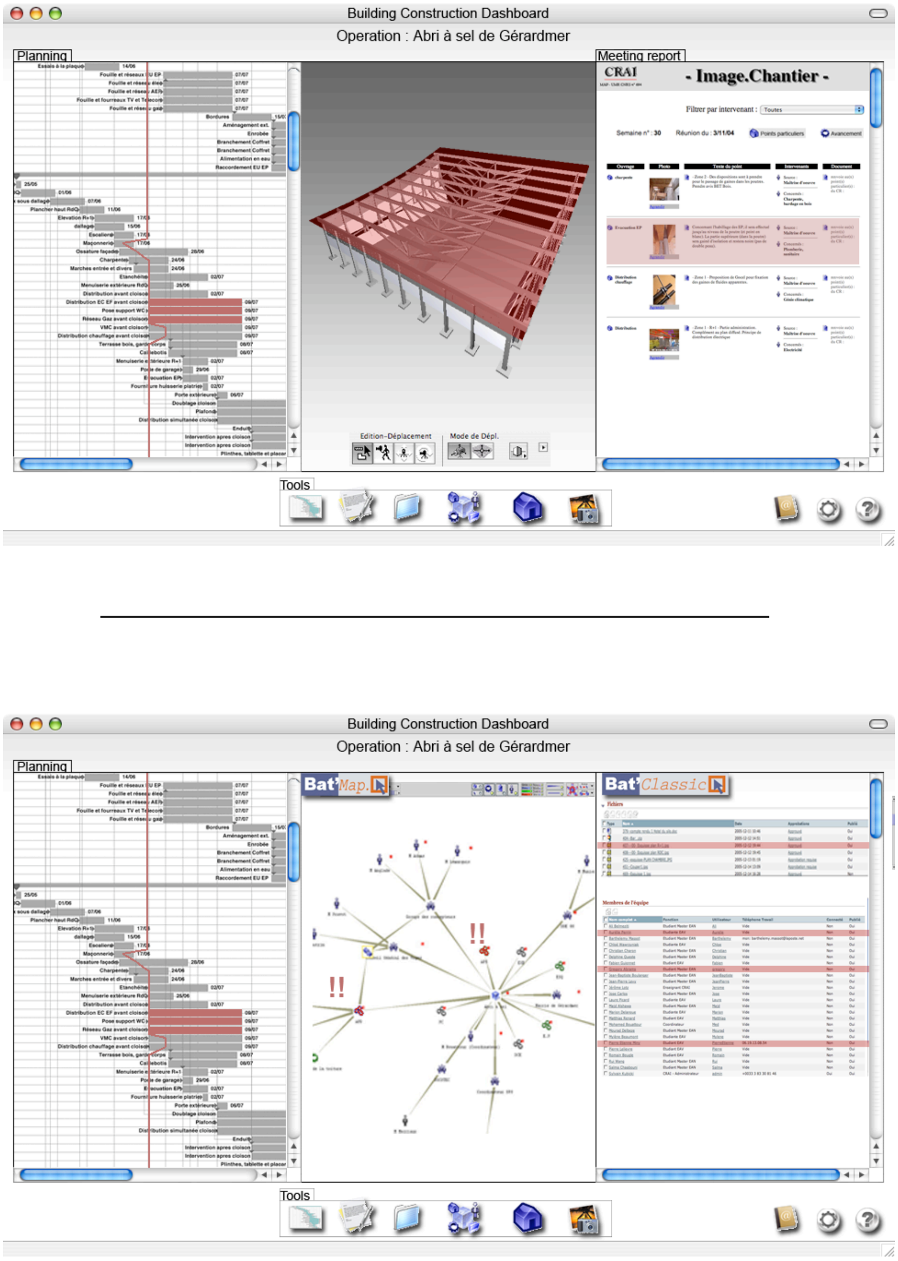

Fig. 5. A hypothesis of the dashboard interface – Architect view (top) and pilot view (bottom)

4.2 Infrastructure driven by models

We are working at present on the definition of the infrastructure into which the dashboard will be inserted. Its vocation is to centralise information. So this tool is placed at the intersection of the usual tools of each actor. It should be added to a project management tool, comprising all information about the cooperative project. Its structure should be an instantiation of the cooperation meta-model.

The use of multiple views in the dashboard requires modelling visualization modes existing and used in other tools: text, table, 3D mockup, graph, Gantt diagram, 4D visualization [19] etc. The choice of a visualization mode to represent information is made through certain criteria: information type to be visualized, usual practice of a tool, skills of the user etc. We envisage defining transformations between cooperative context model and visualization mode models in order to manage these correspondences.

Figure 6 shows these transformations between models at level M1 and their instances: information selections generated at level M0, e.g. for display in the dashboard.

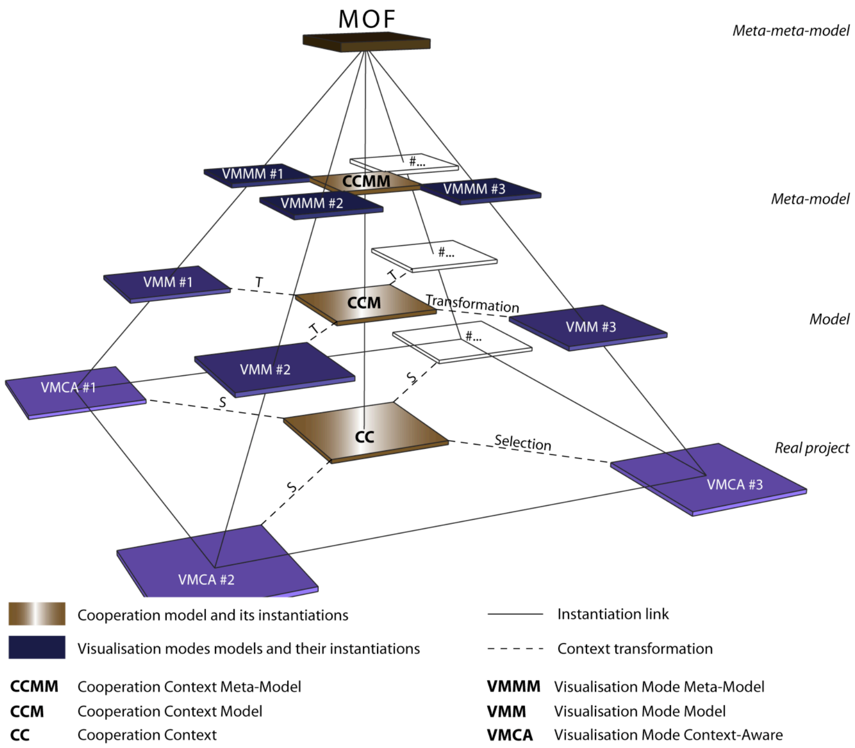

Fig. 6. Infrastructure driven by models

4.3 Perspectives

The future development concerns firstly the finest definition of the dashboard tool: information content and indicators used. Information representation will use the architecture described above. It allows us to select information to be represented in a database of the project and to display it for the user in the dashboard. We have now to develop a context adaptation "module", managing user information: his role (and his rights to information), his preceding actions and possibly his potential needs.

The dashboard function is to display synthetic information for coordination and to redirect the user to other tools. We also imagine allowing the user to carry out actions directly from the dashboard (modifying a date, sending a request…) and so to modify the cooperative context.

In the cooperation meta-model (part 3) these actions should be defined for each entity ("operations" in UML formalism). However possible actions are strongly dependant on the capacities of the used tool. We now are working on an extension of the meta-model with the "tool" concept.

5 Conclusion

The objective of the proposition of a model-based infrastructure and a cooperative platform comprising usual and new tools is to give each actor a relevant vision of a cooperation project. This model-based platform allows the representation of the cooperation context and gives it the malleability it needs to be adapted to a specific cooperation project. The model infrastructure establishes relations between cooperative context elements and their representation in specific visualization modes. This work is currently in progress. We have to define the exact nature of transformations between models and the techniques to use to realise it.

The cooperative platform consists in a project management tool developed at the CRAI laboratory for a few years and dedicated to the AEC project context: "Bat'Group". It is able to manage project context information (actors, documents, activities and objects of the project). We are now developing a context adaptation module to identify and manage information about users.

Building construction dashboard is a new tool, suggesting an innovative view of information for coordination. The objective we want to reach is to give the user an adapted representation of information. It should allow him to better understand the cooperative context of the project he is working on.

We have now to define what visualization modes are well adapted for which user, relatively to his role, his skill etc. We analyse also the possibility of interface adaptation by the user. Finally, tool ergonomics is also in question especially concerning the choice of dashboard indicators.

A major stage of this work consists in validating this proposition with professionals of the AEC domain. We envisage an experiment with architects and pilots, in order to validate some coordination scenarios with and without dashboard.

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