Trust integration in a coordination assistance tool,Application to building construction activity

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Abstract: In the Architecture Engineering and Construction (AEC) sector, cooperation between actors is essential for project success. During the building construction activity, organization is both hierarchical, transversal and adhocratic. Moreover coordination mechanisms are strongly dependant on trust perception by the actors. New assistance tools have to integrate these heterogeneous parameters. The proposition described here consists of the design of a coordination tool providing indicators (about coordination and trust) 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 (multi)visualization.

1 Introduction

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, i.e. there are some working periods contrasting with waiting periods.

Cooperation during building construction consists essentially of the coordination of the independent actors' teams, which don't have a global "vision" of the project context. Their "vision" is very often limited to their contract: tasks and works to build.

We think that the challenge to reach in the design of new tools to assist coordination is to place the user at the centre of the process in order to answer to his particular needs and display information in a way related to his context.

In the first part we identify organization forms that should be found in the building construction activity. Coordination mechanisms identified are strongly relative to these organizations. Moreover quality of the interactions for coordination is dependant to the trust level perception. Finally awareness should focus on coordination information and trust.

In the second part we will describe existing or emerging methods and research works in the field of assistance tools for coordination in the AEC sector.

We will present then our proposition for assisting coordination by taking into account the trust perception. The proposition comprises both a dashboard tool and a multi-view navigation system.

In part 4 we suggest the method we use to setup this infrastructure. The development of this tool is based on a description of the domain by the way of modelling. We suggest a meta-model describing the cooperative activity. This meta-model is instantiated in AEC-specific models. It allows information sharing and context visualization.

2 Cooperation in organizations

2.1 Organization typologies

XXth century theories on organizations focus essentially on their formal structure. Studies by Henry Mintzberg appear especially interesting when it comes to distinguishing between organization forms [Mi79]. We retain here three major forms: *"hierarchical"* organizations, "*transversal*" organizations and *"adhocratic"* organizations.

"*Hierarchical*" organization covers traditional forms identified in theories of Taylor [Ta11]. It's characterised by bureaucracy or organigrams.

When organization becomes more complex and dynamic, we assist to a certain standardization of methods and process. In some cases these organizations cover numerous project's contexts. We will talk then about "*transversal"* organizations.

"*Adhocracy*" concept introduced by Toffler [To70] covers a more "democratic" vision of collective work. Thus decisions should be distributed between actors and personal strategies should be preserved.

2.2 Coordination mechanisms

Coordination is defined by Malone as "the process of managing dependencies between activities" [MC93]. Thompson addressed this theme focusing on the interdependencies between organization's members [Th67]. In the three main types of organizations described in section 2.1, coordination takes different forms.

Henry Mintzberg distinguishes essentially between three coordination mechanisms:
- In *direct supervision* a person is responsible of the others' work. This person has to plan the process and to communicate it explicitly to the actors,
- *Standardization* appears when coordination of the different workers is incorporated in the program in early design stage. Communication need is then reduced,
- *Mutual adjustment* realizes work coordination by the way of informal communication.

In its study on "dimensions of coordination", [An00] highlights two coordination modes: oral coordination and artefacts-based coordination. *Oral* coordination is based on a knowledge background shared by the actors involved in coordination activity. Then, interaction is based on the "focus" or "object of coordination". This type of coordination is found in relatively "simple" domains. *Artefact-based* coordination appears in more complex cases (numerous actors involved, large dimension of the project, high variability). Its advantage is that it is more simple and comprehensive for the actors through the use of representation specific to their domain of expertise.

This analysis is closer to the one proposed by [Go01], which distinguishes between two types of coordination: *implicit* (e.g. mutual adjustment) and *explicit* (e.g. application of procedures described in rules and contracts). Schmidt and Simone suggest the notion of coordination mechanism based on *protocols* and artefacts [SS96]. In other words, it consists of identifying options for a particular situation and explaining it by artefacts.

Through this brief state of the art about coordination, our goal is to make a link between these coordination modes and specific organizations identified in section 2.1 (see illustration 1):
- In "hierarchical" organizations protocols and artefacts are the main methods and tools used to coordinate the teams of actors. This is due to the finely and explicit definition of tasks and process. Direct supervision is the principal form of coordination.
- In "adhocratic" organizations oral communication is very often used. Heterogeneous actors grouped for the realization of a task or activity use "mutual adjustment" to coordinate implicitly. Artefacts furnished by hierarchy are used to better understand problems and to solve it in coherence with direct supervision.
- In transversal organizations, standardization of skills or results is the main mechanism of coordination. This is an organization form largely used in cases of inter-project interactions (actors working booth in many projects). Standardization implies less needs of communication (oral or artefact-based) and a medium level of explicit/implicit.

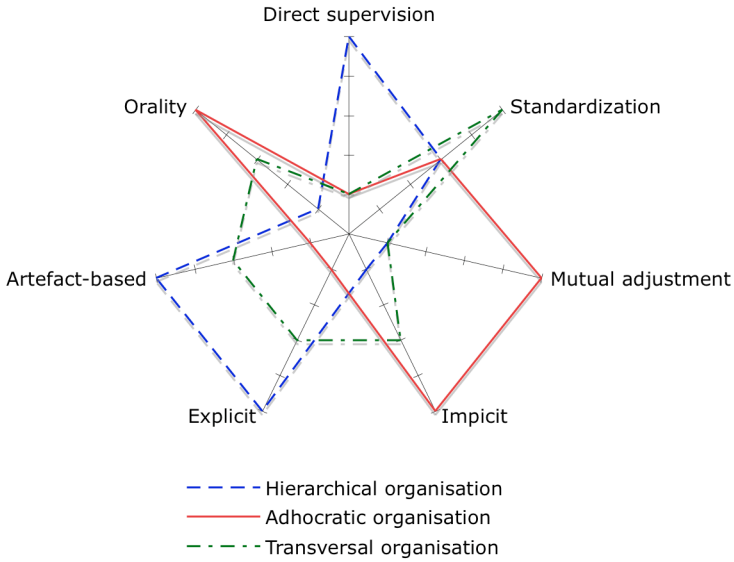

Illustration 1: Organization typologies and coordination mechanisms

Quality of interactions between actors is essential in coordination mechanisms. Trust perception is a major concept to better understand and to increase quality of interaction.

2.3 Trust characteristics in organizations

Trust is a complex concept difficult to understand. Specialists in various areas such as sociology, economy or psychology fail to converge to an unanimous definition. Hardin's definition shows the limited character of trust: "Person **A** trusts **B** to do **Y**". In this case trust focuses on a particular activity and is based on the expectation for A that B will reach the objectives (e.g. delays, cost, quantity or quality respect). Trust is necessary for an actor because risks exist. "A risk concerns the character weakly dominated of the environment, the under-determined actions of others, the unpredictability of activity progress and their undetermined consequences" [Gon01]. Then trust is seen as a way to surpass risk. Without it action and interaction should not be envisaged. A lack of trust should immobilize exchanges.

Works of Zolin [Zo00] describe trust approach in AEC[1] teams. Trust dynamic is perceived during the interactions and during actors' performance evaluation. In these works trust conditions are linked with dependencies between activities and members: pooled interdependence, sequential interdependence, and reciprocal interdependence [Th67].

[1] AEC Architecture Engineering and Construction sector

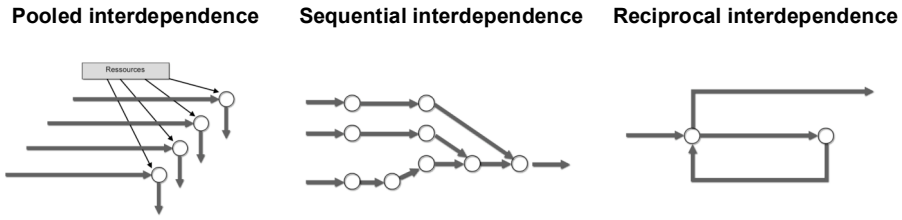

Illustration 2: Interdependencies between activities and members.

In pooled interdependence situation actors share common resources but they are independent. They trust mutually concerning the respect of quality goals, quantity goals and deadlines. In a sequential interdependence situation, input of an actor corresponds to the output of another one. Trust of actor A providing output to actor B necessary for his activity is based on emergency information transmission. Trust of actor B is based on eventual transmission by actor A of information relative to inability for him to achieve specifications or deadlines. In a reciprocal interdependence situation actors transmit mutually work. They have to trust mutually concerning information exchange relative to the impact of decisions on costs, delays or quality. Moreover they have to trust mutually to find solutions concerning booth actors' activities.

The different organization types identified should be associated to dominant interdependencies. Trust will be identified through the perceived risk by actors. This risk is linked to the feeling of process control and to interaction frequency. Evolution informs on speed of trust relation building. Sensitivity characterises the impact of a piece of information on the decision relative to trust.

Transversal organization is the worse situation for trust development. In fact transversal organization is based on pooled interdependence. Interactions between members are reduced, perceived risk is high, evolution is slow and sensitivity is weak.

Adhocratic organization is the most favourable situation for trust development. This organization form is based on reciprocal interdependence. Interactions between members are frequent, perceived risk is weak and trust is characterised by fast evolution and weak sensitivity.

Hierarchical organization is an intermediate situation. This type of organization is based on sequential interdependence. Perceived risk, evolution and sensitivity are intermediate.

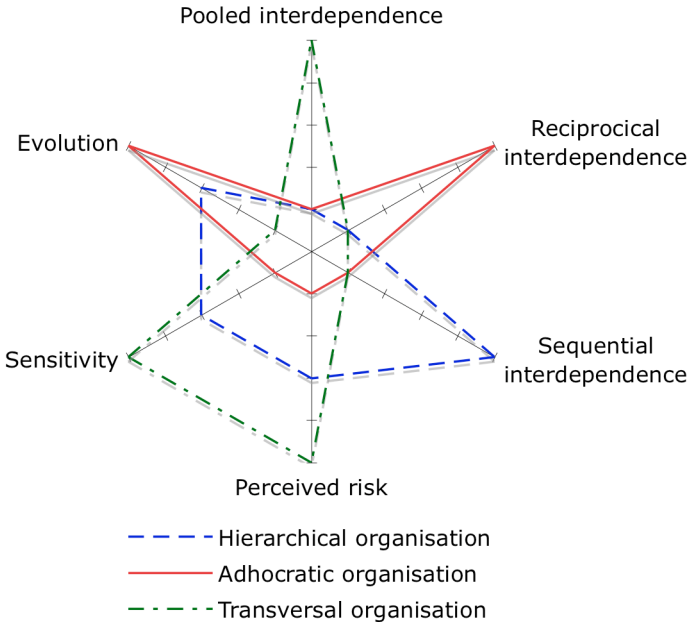

Illustration 3: Trust characteristics in organizations

2.4 Trust and coordination in awareness processes

Coordination quality and trust perception are intimately linked with awareness developed by the actors during a project.

Especially in "adhocratic" organizations characterised by ephemeral teams and mutual adjustment between actors, group awareness favours informal and unanticipated activities [Gu97]. For Lucy Suchman « actions are often socially and physically situated and situation is essential for action interpretation" [Su87].

We retain especially here the 3 levels of awareness process defined by Mica Endsley [En00]:

- The perception of relevant elements in the environment,
- The comprehension of these elements,
- The prediction of the state of these elements in a near future.

An awareness tool should provide the user with indicators about coordination: progress of the activity, new actors or documents exchanged. Such a tool has also to select and display information allowing the actors to increase their trust level perception. Indicators of trust level should be: risk level (on artefacts, actors, tools or activities) or interaction frequency etc. The "comprehension" level is generally achieved by the use of specific tools allowing the actors to understand a situation. We suggest to navigate in the context of the project through different representations in usual tools (see part 4).

3 Tools and methods to assist cooperation

In the building construction projects organization varies between hierarchical level (e.g. pilot supervises contractors) and adhocratic level (mutual adjustment between 2 contractors on the site). Transversal organization is identified for example for the actors intervening punctually on multiple projects (supplier, control organism). Coordination modes vary also between direct supervision (task planning, coordination meeting), standardization (skill of an external actor, desired result) and mutual adjustment (informal meeting between 2 actors). Finally trust perception should be strong (mutual adjustment on the site) or weak (task planning).

AEC 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 etc. Awareness for coordination and trust is a way to surpass these difficulties. New methods and new tools have been developed for some years in order to take into account these limits of coordination.

3.1 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 [FP05] 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]. In this way each “object” represents a concept of the AEC domain (e.g. a built-work or a specific document).

But these new methods remain quite unusable for every-day work. They come from other activity sectors such as manufacturing industry and are not well-adapted to the AEC context and its particularities: changes in the project, uncertainties, informal coordination. Moreover they don’t take into account trust perception by the users.

3.2 Research work in Information Technology

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

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

Works on context aware applications in mobile computing or in artificial intelligence [Br02][Do03] 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 [DA99] a context aware system "uses context to transmit adapted and relevant information to the user".

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 [VR92] 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) developed by J. Rasmussen. This approach tries to model information treatment carried out by humans [Ra86]. This taxonomy is a guide for displaying information in a way adapted to the cognitive and perceptive faculties of humans.

4 *Bat'iViews* : A cooperative context multi-view interface

Coordination of the actors and trust perception are essential elements for cooperation quality in a building construction operation. With this focus, we have been interested in awareness theories [En95][GG96]. Mica 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,
- Comprehension of these elements,
- Prediction of their state in a "near future".

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. Moreover trust perception between actors should be realized through indicators (see part 2.4) which find information in the diverse sources of data (documents, platforms).

Our proposition consists of specifying and designing a multi-view cooperative platform dedicated to building construction. This platform will include a specific and modulating multi-view interface. 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 [Fe05].

Based on awareness theories we suggest defining functions for the building construction cooperative platform:

- Context perception: The dashboard view presents information in a way adapted to the user (e.g. his role, his needs). With the focus of measuring performance, indicators have to be chosen in order to alert the user about problems happening during process progress (e.g. delay on a task).

- Comprehension: It consists in allowing the user to visualize coordination information using content-adapted representations (text, graphs, 3D mock-up). A three-frames view is developed to use multi-view of the same information in order to better understand it. But information it-self is not enough. That's why the platform will be connected to other tools adapted to the comprehension of problems,
- Anticipation: The user should anticipate himself the future state of the process, based on indicators of the dashboard and understanding through multi-view. But if the process is modelled the dashboard should also monitor its progress and warn the actors of risks.

Illustration 4 shows hypothesis of interface design for the multi-view interface called *Bat'iViews*[3]. At present, we suggest some different visualization modes in the window, used in other tools (Gantt view, 3D mock-up, text and graph). These visualization modes (that we call *Board'Gets*[4]) are arranged on the screen specifically to the user context.

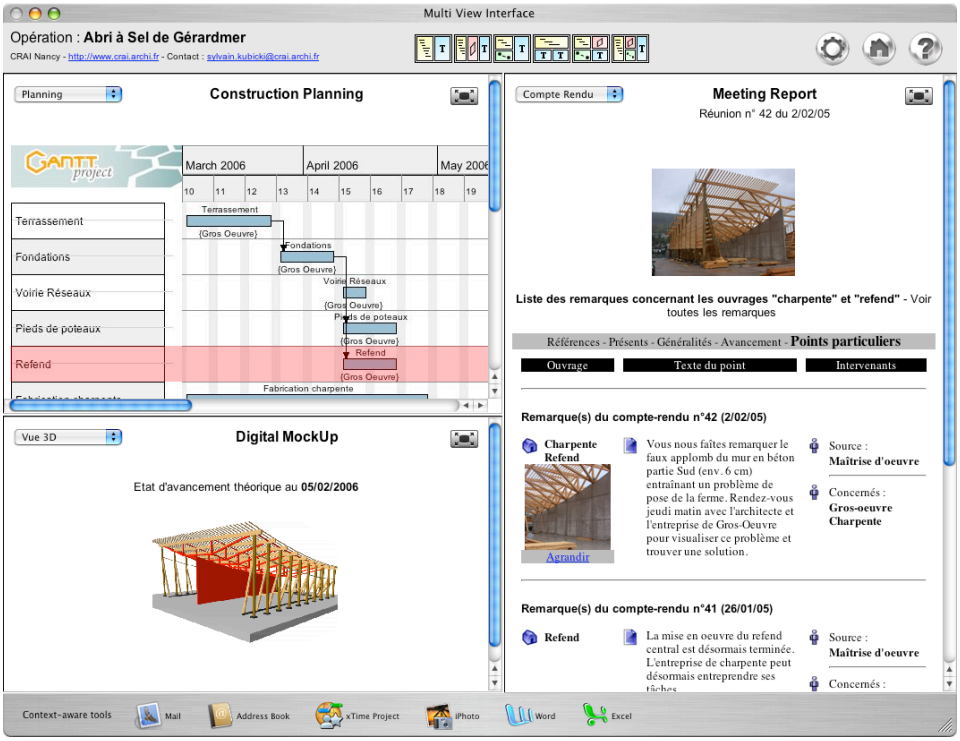

Illustration 4: Multi-view interface *Bat'iViews* : hypothesis of view arrangement

[3] A demonstration is available at http://www.crai.archi.fr/BatiViews
[4] Board'Get: Concatenation of dashBOARD and widGET.

The arrangement of views presented in illustration 4 is dedicated to an architect. The representation focuses on 3D visualization, which is relatively common and comprehensible for an architect. 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). Buttons on the bottom allow the user to change *Board'Gets* arrangement. They can switch from an arrangement to another. 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.

5 A model-based architecture for platform development

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. Some other works have suggested models to represent and describe cooperative activity mediated by groupware tool. For example DARE model [Bo99] based on activity theory, suggests to represent activity through the concepts of task, role and tool.

5.1 Meta-model approach and objectives

The definition of a meta-model allows us to highlight essential abstract concepts to describe cooperation context 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 [Sp99] is used in the standard MOF (Meta Object Facility) and is proposed by the OMG (Object Management Group). 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.

5.2 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. Modelling these concepts of cooperation will allow us to develop domain-specific applications structured on the base of the *cooperation meta-model for design and realization*.

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 [Kr99]. 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 realization 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 or 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 to define which tool should be used by an actor (e.g. related to his role, his skill),
- The relationships between tools and activities describe how tools should be associated to specific activities which are completely or partly automated,

- The relationships between tools and artefacts are relative to the function of the tool: what artefact it produces or manages. Some tools are exclusively dedicated to the visualization of information.

- And so on.

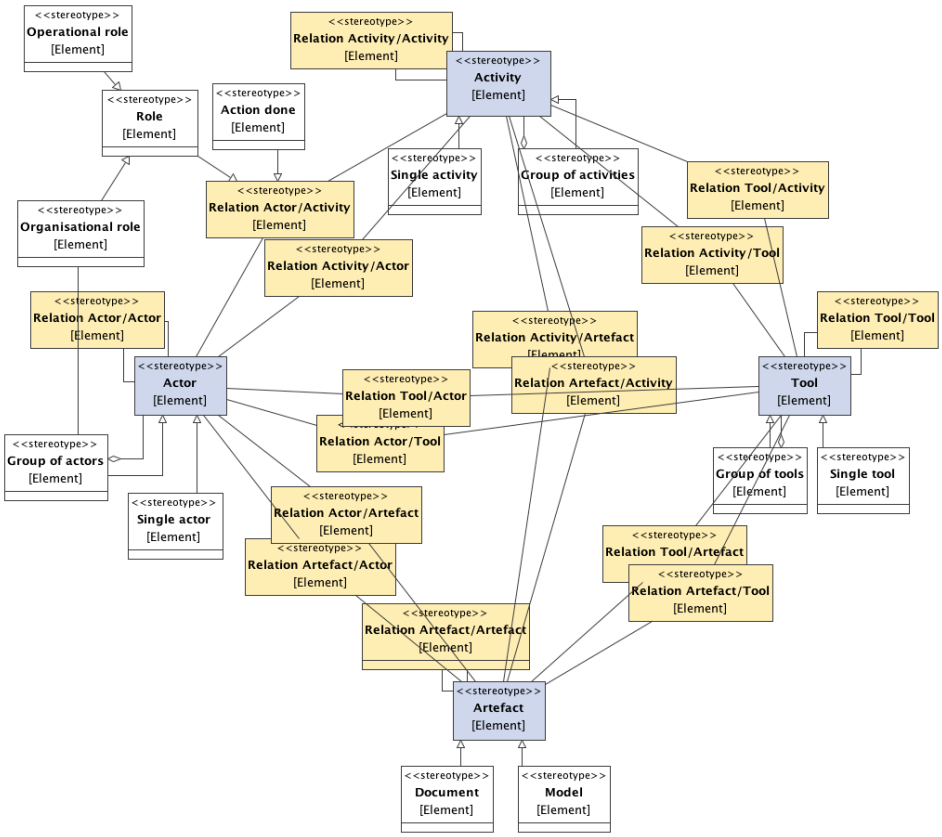

Illustration 5: Meta model of the cooperative context (extract)

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

5.3 Multi-view infrastructure driven by models

The model architecture presented above is essential for structuring information. We are working also on the links existing between this cooperative context and the tools allowing the visualization of this content. The platform described in part 4 uses several visualization modes (called *Board'Gets*) 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 *Board'Get* has to be described by a model. By using the same model architecture described above, we obtain a meta-model (M2) of the *Board'Get*, its model (M1) (describing the elements of the graphical interface) and finally its instantiation in a real interface M0.

Illustration 8 shows an example of instantiation M1/M0 in the case of Bat'Map application [Ha03]. 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 *Board'Get*.

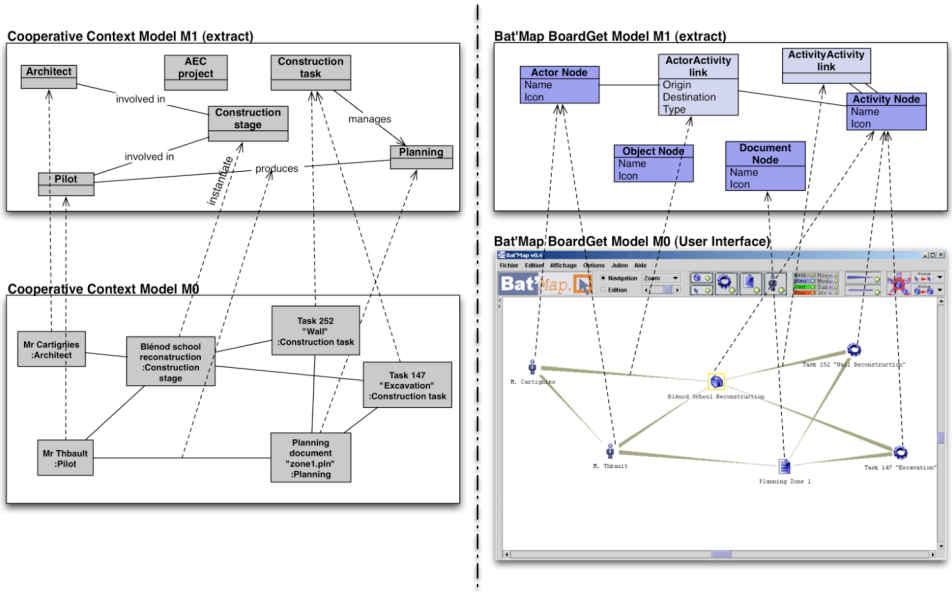

Illustration 6: *Board'Get* interface, its model (right) and cooperative context (left)

5.4 Model transformation rules to build visualization *Board'Gets*

Transformations are also described in the MDA architecture from the MOF. To do this, cooperative context and its visualization mode are considered as models (see illustration 9). 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 this 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 will be used to specify the transformations. ATL is a transformation language for MDA and is able to translate EMF[5] 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.

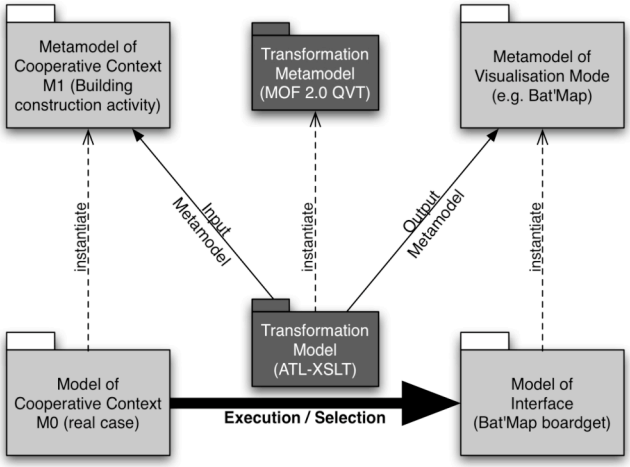

Illustration 7: Transformation architecture

In order to illustrate this architecture we will describe the visualization of a cooperative context in "Bat'Map" *Board'Get*. The model visualized in this BoardGet is an interactive graph where nodes are actors, activities, documents or tools (M. Cartignies <Actor Node>, Blénod school reconstruction <ActivityNode>, Planning zone1.pln <Document Node>, ProducesLink <ActorDocumentLink>). The meta-model of this BoardGet defines the types of nodes and the types of links needed to represent this cooperative context (ActorNode <Node>, ActivityNode <Node> and ActorDocumentLink <Link>.

[5] Eclipse Modeling Framework (EMF) is a modeling framework and code generation facility for building applications

Visualization of this context by the user needs to select the relevant entities of the context in the database, and then to apply the transformation model defined at the meta-model level. This model comprises a set of rules describing transformations from Cooperative Context entities to BoardGet entities: Actor → ActorNode / Document → DocumentNode / ProduceRelation → ProduceLink

These rules will be defined in the ATL platform and then translated in XSLT format to be set up in our experimental platform Bat'Group.

5.5 Perspectives

The future development concerns firstly the finest definition models necessary to the generation of *Board'Gets* views (i.e. user-task model, view model and others). We will then define the specific interaction between views and relative models transformations.

The dashboard goal is to display synthetic information for coordination and to redirect the user to other tools. We also imagine to allow the user to carry out actions directly from the dashboard. In the cooperation meta-model (illustration 6) these actions should be defined for each entity. However possible actions are strongly dependant on the capacities of the used tool.

6 Conclusion

Organizations regroup actors achieving a common goal. They take different forms and use particular interactions to ensure coordination of the activities. Trust perception influences largely these interactions.

In the building construction activity the organization evolves continually between hierarchical and adhocratic levels. Coordination mechanisms identified are then adapted to these variations. Interactions between actors occur in a trust context evolving itself through the different activities.

The proposition described here consists in the design of an assistance tool for coordination during building construction. This tool takes into account the various organization and coordination forms, such as the characteristics of interactions, in order to display information to the user in a way adapted to his context and his needs.

Based on awareness theories we suggest two essential stages in the use of the tool:
- A perception level consists in suggesting indicators to the user. These indicators are linked to the coordination of the activity and to the trust level in interactions,
- A comprehension level allows the user to navigate in the cooperative context information by the way of a multi-view interface.

To realize this infrastructure we have developed a model of the cooperative context. We put it in relation with models of visualization modes in order to build the multi-view interface. Transformation models allow us to build rules necessary to this relation.

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