Assistance to cooperation during building construction stage. Proposition of a model and a tool.

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Abstract

The article focuses on specificities of building construction stage as cooperative activity. We identify lacks and limits of coordination methods at present used in the building construction stage. Our propositions consist firstly of a model to represent and describe the cooperative activity in a construction project. Then we analyse the use of the point of view concept to develop interfaces with users of a new tool. Finally, we discuss about the role of the image in assisting the transmission of coordination information during building construction. These analyses allow us to develop a prototype tool to assist transmission of the information usually contained in the building construction meeting report. We describe finally the experimentation of this tool in a real project, at present in progress.

Keywords

Building construction, Cooperation, Coordination, Building construction photography.

1. Introduction.

Many areas of research have tried to characterise architectural design and particularly its specificities as a design activity. In fact, the project in the AEC sector can be distinguished by some specificities, in particular the numerous points of view which are used by the different actors [1] or simply the nature of the object in design [2]: the building.
The building construction stage reveals some specific problems that we will try to identify in this paper. We will focus here particularly on the cooperation existing during the building construction stage in order to underline the nature of this activity, the structure of working teams, and the methods of coordination commonly used. In this cooperation context, the role of a tool is to allow the actors to have not only a vision of their work development but also to increase their action's potential. In the building construction stage, the coordination of teams is an essential activity.
In the first part, we will describe the framework of the cooperation in the design and construction stages, as well as the characteristics of the cooperation in architectural design and construction. Then we will describe the existing methods of coordination and their limits. In a fourth part, we will develop an analysis of the construction activity: modelling this cooperative activity, describing the concept of point of view and demonstrating the benefits of the use of image. Finally, we will describe our tool prototype: *Image.Chantier* and the experiment in progress.

2. Context.

Architecture, Engineering and Construction Context.

The AEC sector is where important developments take place concerning the building itself (environmental or construction quality), and concerning the methods used in engineering and construction, from design to building construction (concurrent engineering). "Quality

charts" are at the base of many projects. They concern the quality of the realisation (architectural quality, building materials or ambiance) but also the quality in the work methods of the different actors: time, costs or communication management.
We can identify the quality of cooperation between the different teams of a project as a determining factor in the project's success and quality.
The cooperation in design and construction has a specific context. It can be distinguished by the numerous uncertainties in the project definition, at its different stages. We think that one of the goals of cooperative activities is to anticipate and reduce these uncertainties.

AEC sector particularities.

We can identify explicitly some of these particularities and their properties:

- **The teams of actors**. They are generally heterogeneous in size and function. The actors themselves can be distinguished by their level of knowledge or the number of projects they are working on. Finally, the global team is constantly recomposed during the progress of the project.
- **The documents**. The AEC sector is also characterized by the quantity of documents exchanged and by the various natures of these documents: 2D plans, digital mock-up, textual pieces (i.e. contractual descriptions), or schedule. For each one of these documents, it's necessary to take into account their release and their diffusion path (sender, receiver(s)).
- **The nature of the object in design**. The building and its particular elements are objects which have particular relations with their environment. The design work has to find solutions to different problems [3], such as structure, geometry but also thermal or acoustic comfort. The construction of the building refers to technical and technological rules depending on the building materials or the nature of the structure… This particular design object is a unique production, a prototype. In consequence, the rules commonly used in the design of industrial products cannot be applied in the AEC sector.
- **The activities**. Various documents produced allow the designers to define the critical stages of an architectural project, but it is very difficult to identify clearly the duration or the exact end of the different tasks. In many cases, the design of the building is not ended when the construction begins! On the contrary, at the building construction stage, we can identify more clearly the tasks to be carried out: planning of the different tasks by actors, critical paths etc.

Related works.

Assistance to building construction is the focus of numerous research works. The development of Information Systems allows researchers to apply innovative technologies to the AEC sector. We can distinguish two main aspects of building construction instrumentation and assistance to actors:

- Assisting building construction progress, i.e. tools to assist the planning activity [4] or to optimise stock and exchange of materials on the building site [5].We have noticed a field of research which suggests the monitoring of construction progress management by photography [6].
- Knowledge management linked to the construction project. The prototypal character of each project makes its realisation more complex because each problem must be solved from scratch. The use of Information Systems can enable the capitalisation of knowledge of a project and the sharing of this information [7].

Problem.

Our study tries to characterise the activity during the building construction stage, from the point of view of cooperation between actors. Previous works have been developed in the CRAI laboratory in order to define a cooperative framework in the architectural design. We are interested here more specifically in the particularities of the building construction stage. A model of the cooperation in architectural design has been developed. This article describes its extension to the building construction activity.
We can briefly analyse the under-use of tools based on IS nowadays, particularly in the building construction activity. There are very interesting possibilities, for example in the use of digital photography by the different actors in the construction.

3. The existing activities of coordination.

Aspects of coordination during the building construction stage.

The building construction stage is the project stage where the object (the building) moves progressively from a virtual state to a realised state. The complexity of this stage is due to many factors such as the number of actors or the prototypal character of the building (many design problems are discovered during the construction stage). Numerous aspects have to be faced:

- Respecting deadlines (anticipating problems and solving conflicts),
- Costs management,
- Quality of execution of the different building elements and conformity with the original drawings.

In consequence, nowadays new activities are introduced in the building construction stage: coordination activities, security management or environmental advice.

Coordination activities.

There are two major activities allowing the control of the coordination in the building construction process: planning and coordination meeting.

- *Planning*.

This activity consists of the examination of each intervention in the elementary tasks to determine the sequence of these tasks and the critical path to respect. Planning consists of defining the realisation of these tasks chronologically (starting date, duration).

- *Coordination meeting.*

The "building construction meeting", generally once a week, allows the coordinator to verify the progress statement with all the actors involved in the operation, and particularly to identify and solve the existing or anticipated problems. A meeting report is produced, validating the decisions taken during the meeting and the information distributed.

Limits of these activities in building construction management.

The objective of these coordination methods is to ensure the correct progress of the building construction. We can identify some limits to these activities:

- Generally, coordination activities are the source of a large quantity of information (i.e. textual piece, note, sketch). The problem is that the methods used don't allow the creation of links between information or the easy tracing of this information,
- The information is diffused in its totality and to every actor involved in the project. But we can notice that all the information is not useful to every actor…,

- Finally, the communication form of the coordination information is very basic. Distribution and consultation of the documents are not controlled (use of fax, postal mail).

Emerging tools and activities.

For some years, we have seen a development in the use of digital photography, and particularly at the building construction stage. At this stage, the different actors can use it to communicate more efficiently: discuss problems or illustrate a construction sequence…
Some "groupware" tools have been introduced principally to manage the project's documents. They are largely under-used and unknown by the actors of the AEC sector.

4. Analyse of domain and needs.

Based on these considerations, we have developed a model and a building construction assistance tool, taking into account the specific needs of this activity. The integration of Information Systems into the building construction stage has to increase coordination quality and capitalise the site experience in order to re-use it in other projects.
In this part, we analyse three problems which seem to be essential in the design of an assistance tool for the building construction stage: modelling the activity with the cooperation point of view in order to better underline the specific needs, analysing the different points of view on this activity and using digital image as a technical information support media for coordination.

Characterising and modelling cooperative activity in a building construction project.

We suggest here analysing the activity in a building construction project from the point of view of cooperation between actors (exchanges, dependencies). Modelling these concepts of cooperation in the AEC sector will allow us to develop specific applications structured on the base of the *cooperation in design and construction model* [8].
The context of cooperative design and construction has to represent relations and interactions between the actors, their activities, the documents they produce and the object of the cooperation: building elements or spaces (see figure 1):

- **Actor**: 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.
- **Document**: a document represents a professional « deliverable » part of a contract. The actors generate documents during activities.
- **Activity**: the activities inside a project have several "scale" levels: project, stage, milestone and task. The activity can also be characterised by its nature: design, execution, planning, coordination, and prevention activities.
- **Object**: The object is the goal of the cooperation project. We distinguish two types of objects: building elements and spaces. Its definition evolves from design to construction stage: from virtual to real building.
- **Relationship**: a relationship identifies a type of link existing between two elements:
    - The relationship between actors depends of the social organisation of the group (hierarchical relationship),
    - The relationships between actors and activities define the role of an actor in an activity (operational role, organisational role),

- The relationships between actors and objects depends both on the role and the activity: drawing, calculating, building,
- The documents can describe the object (graphical or textual information),
- The relationships between activities are relative to planning: following, preceding, being included in, and so on.

Information regarding the context of the collaborative project can be represented and described by our model:

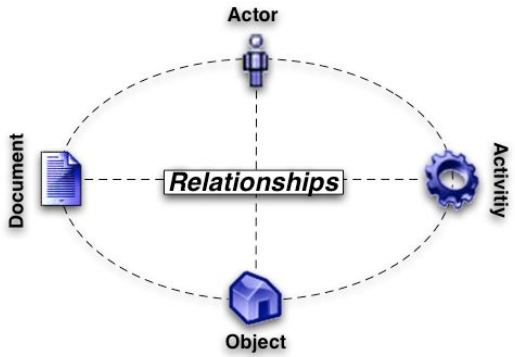

Figure 1. Model of cooperation in design and construction.

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

The point of view as the main concept in the relationship with users.

Our aim in introducing the concept of *point of view* is to offer a tool allowing the user to extract the contextual information from the project statement in order to answer a particular need. The main point is to build a dynamic and adaptive data model referring to the problem.
There are two direct applications: on the one hand the possibility to offer an adaptive visualisation of information and on the other hand defining an action potential for the user depending on the context.
In the concurrent engineering sector, the point of view is an index of the design elements referring to a designer. The structure of the point of view is the ideal structural view to help understand the system [9].
The point of view should have different forms:

- It can represent an approach or the position of an actor,
- It can represent an aspect of the problem, focusing on the activity or on the object.
- The direct application of this point of view concept is the set-up of filters in a cooperative tool.

The digital image: privileged media for its qualities in illustrating points of view.

Nowadays, the image is a support largely used to carry information. In this research on new tool specifications to assist the building construction stage, we have analysed the characteristics of building construction digital imagery and its potentialities.
The particularity of building construction image is that it shows an object being fabricated.
We must distinguish between three particular characteristics [10]:

- Image illustrates the building construction's general progress, or particular "works under construction". In this case, image plays a **proof role**,

- Image illustrates everything or a part of a point a view on a building element or an activity. It has a **heuristic function**,
- Image can transmit information contained or be a tool to access other related information (illustrated by images). It therefore enables the user to **capitalise on knowledge** of the terrain.

Proof of realisation of building elements.
We can say that the picture, taken on the building site, at a precise time represents a **progress statement of the building construction process**. Independently of the later use of this image (communication, archiving or deleting) the photo is proof of the building construction progress statement.
It is interesting to link this function with the particular character of the meeting report. In fact, this document is a coordination tool. Its content refers to concepts described here: progress statement of a building element, detail of construction process, interfaces between actors… Therefore, for some years we have been seeing an emerging use of images in meeting reports.
Heuristic function of the image.
The building construction image allows the user to identify new problems that haven't been seen with other methods. Its large distribution (i.e. with an Information System) allows other actors (such as the owner or engineer) to give their opinion or to solve problems from their distant workplace. We think that photography could be a way of understanding the context of the building project.
Capitalisation of knowledge of the terrain.
Using the image to represent a phenomenon or an object is not innovative. We would say here that such practices are current among architects, who take photos of their realisation or building site. Their goal is to **capitalise knowledge and skill**. The use of an index method will allow future search in the image base (e.g. precise operation or particular work image search).
Our proposition consists of the development of a **shared knowledge base**, using an index of images based on an ontology relative to cooperative design and construction. The image would be described by semantic information from the AEC sector (e.g. building element, actors) and by coordination information such as the progress of a building element construction, the geographical zone etc.

5. Image.Chantier prototype.

In this study of coordination during building construction we were very interested in the coordination meeting. As we said before, the goal of this meeting is to validate building construction progress (regarding the schedule) and to anticipate and solve new problems.

The meeting report.

The goal of this document is to regroup every piece of information exchanged during the meeting and to ensure its transmission to the different actors [11].
Its structure is generally composed of three parts (see figure 2):

- **General information** relative to the meeting and the building construction process: participants' table (presence, absence), firms workforce, bad weather days,
- Information of **building construction progress**: tasks (finished, in progress, to be done), and coordination (execution planning),
- **Particular points** describing problems (solved or to be solved), remarks…

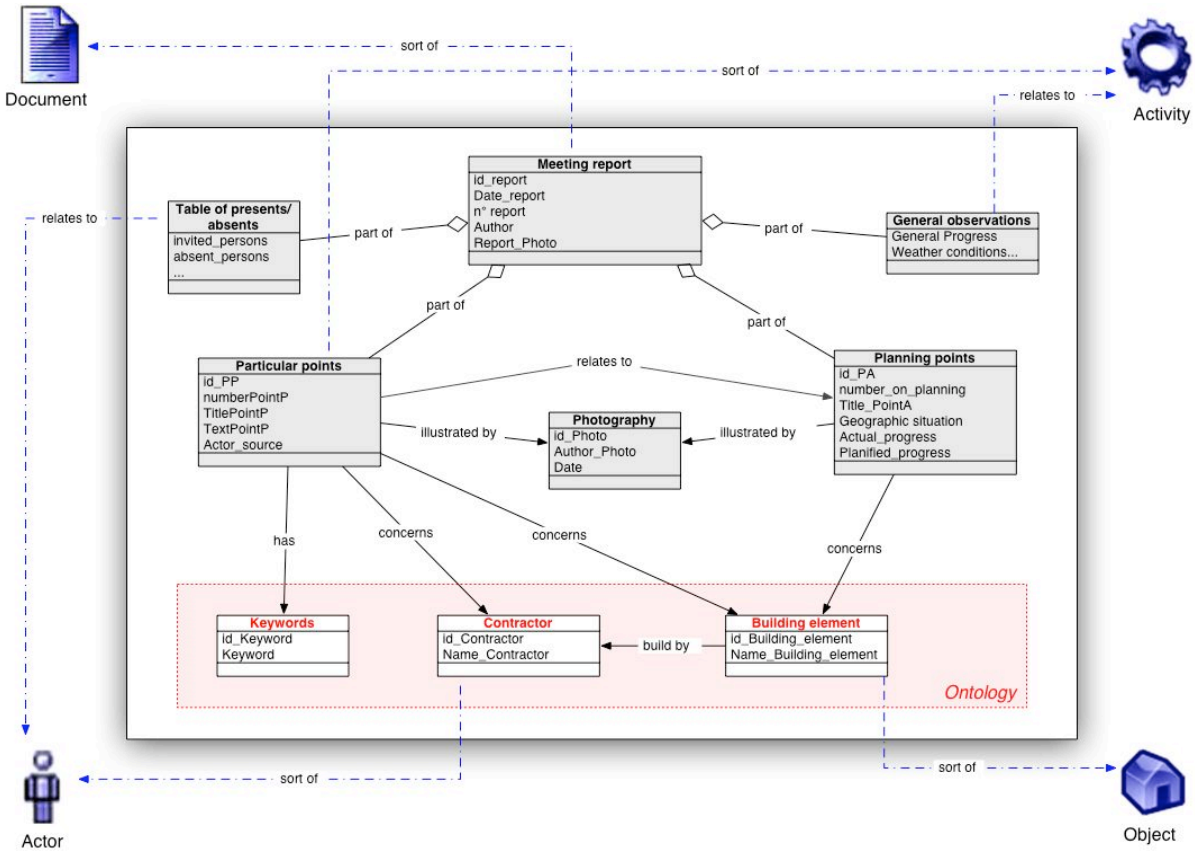

Figure 2. Meeting report conceptual data model.

We can note that the concepts extract from the meeting report can be linked with those exposed in our model of cooperation. The "sort of" relations represent these links. In this way, this document is a great coordination tool for the building construction process.

Specifications for the development of an Information System applied to the meeting report.

The analysis developed in the fourth part of this article allows us to suggest some specifications applied to the building construction meeting report. The objective of our new tool is to offer to users an alternative visualisation of the context of project:

- Structuring information relative to the building construction process, based on the model of cooperation in design and construction.
- Personalising the information displayed to the users with filters (points of view on the process in progress),
- Using the building construction photography as information and cooperation support media.

We have developed a prototype tool based on these objectives. This tool uses a database, allowing us to structure and manage the information in relation to the model of cooperation (see figure 3). Web interfaces, with a protected access, allow the diffusion of coordination information to the actors.

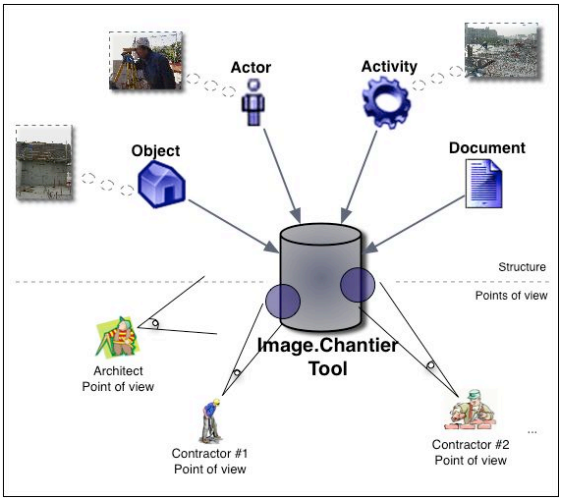

Figure 3. Structure of the information in the tool.

Base concepts of the prototype.

The objective of our prototype is to demonstrate the capacities of a new distribution of coordination information. In this framework, we have restricted our development in order to isolate some concepts:

- The progress points: information relative to the progress of a building element,
- The particular points: information and description of a singular problem. They are characterised by a sender (author) and one or many receivers,
- The integration into an Information System allows us to manage some points of view: the prototype, in its present state, offers the user filters of the information,
- The model demonstrates that links can exist between different types of information: i.e. a particular point should concern one or many progress points. The tool suggests a chronological link (pictures of many state of progress) and a geographical link (surrounding building elements).

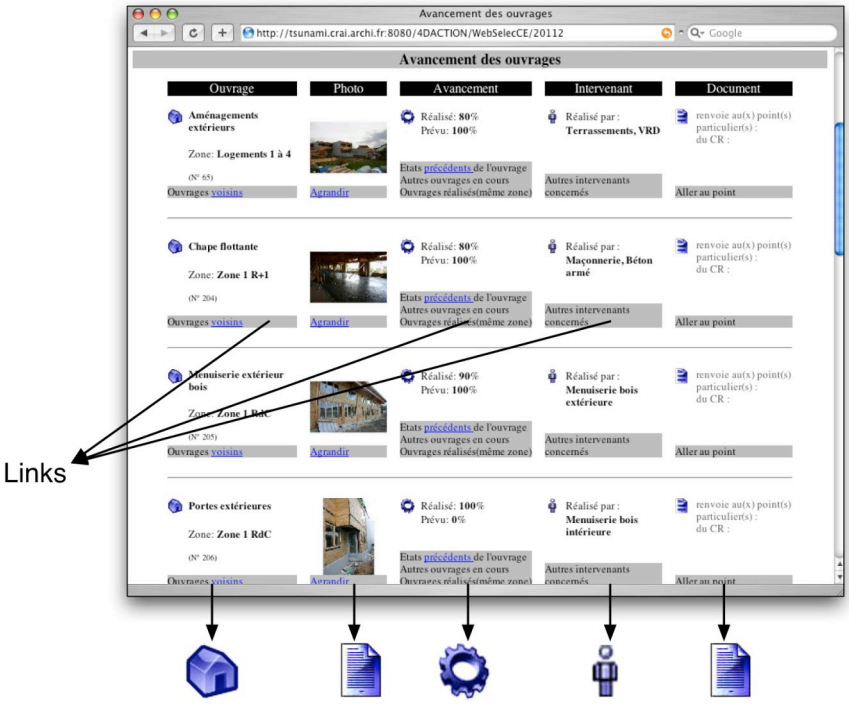

Figure 4. Visualisation of progress points interface.

Figure 4 represents a view of the web interface to display progress point information. We can see that the information displayed is structured with the concepts of the model of cooperation. This structure of interface offers contextual information referring to the specificities of the building construction activity.

6. Experiment.

Experiment framework.

This tool is at present being experimented in a building construction site. We distinguish between three stages of experiment:

- An analysis of the needs, working in collaboration with the different actors to the specifications, and the development of the prototype,
- Use of the tool in the framework of the real operation by the different actors to visualise the coordination information,
- Validation stage.

We notice that users have no particular knowledge of the use of IS based tools, and that the exchange modes used at present are basic: fax, postal mail and sometimes e-mail.

Objectives.

This experiment in a real case of building construction has three main objectives:

- Defining the relevant information for coordination,
- Validating the functionalities of the tool: structure and visualisation of the information,
- Verifying the benefits of building construction imagery in communication between actors.

Validation procedure.

The validation of this experiment and of the first results obtained are still in progress at present. There are some difficulties due to the nature of our proposition: replacing existing communication methods, which are considered as quite efficient by the actors.
That's why we have developed two forms of validation:

- Interviews with the users allow us to validate the efficiency of the displayed information, and the interest in a new tool based on IS.
- An investigation based on questioning in order to evaluate the interest and the real use in detail.

First results.

The validation of this experiment is still in progress, but we can underline some encouraging results revealed by our informal interviews with the different actors on the building site.

- First, the tendency to use new tools based on IS seems to be largely accepted by actors. Nevertheless they are not ready to use such tools in their companies,
- Then, we have noticed a regular use of our tool by some actors: the owner and some members of the engineering team. They were interested in the possibility of having a look at the building construction process without regular visits on the site,
- We can say too that the "proof effect" of the building construction image is globally acknowledged (verifying of the observed result compared to the expected result),
- Finally, it seems to be confirmed that the image carries out a function of anticipation and identification of new problems, particularly for distant users.

7. Conclusion / Prospects.

We have seen in the first parts of this article the major role played by actor coordination in the building construction stage in order to ensure the global success of the project (respecting deadlines and costs). Our proposition consists of an assistance tool to increase coordination quality. The meeting report seems to be the better medium to centralize all the information relative to building construction in progress. In a near future, we can imagine that its diffusion will only be made electronically.
The use of Information System to assist the production and consultation of this document leads us to imagine new methods for data entry [11] and for information diffusion (Man Machine Interface).
Our contribution consists of modelling the cooperative activity in order to better describe the exchanges and to offer an infrastructure based on AEC sector knowledge representation. We underline too the importance of groupware tool adaptability: adaptive visualisation depending on the point of view and potential of action depending on the role. Finally, we suggest a regular use of building construction imagery to illustrate notable construction situations.
The prospects opened up by this work are quite numerous. We will continue this study by validating our hypothesis in the framework of experiments. Then, we have to work on information visualisation (i.e. relationship between image and planning) and especially the point of view concept. The work will focus now on modelling the context of cooperation in design [12] and construction stages in order to better understand and use the contextual information in groupware tools.

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