The Virtual Cooperative Project: An Aid to Building Cooperative Design

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Abstract

The main objective of our research is to develop a tool that helps the management of a building project and aids cooperative design. In this paper, we present a cooperative system called Bat'Map developed according to the model of the Virtual Cooperative Project. This new model of cooperative design takes into account the relational organization of the project and the semantic meaning of works. This system lets geographically dispersed project actors model the project context of a building. More specifically, it allows interpreting, using and exchanging project works in a centralized virtual environment during the building life cycle. This system uses IFC objects which associate in the same model the semantic and the 3D representation of building works. This research represents a new approach because it not based on management of documents but on all data relative to works. So, in the first part of this article, we propose to view collective typology of building domain activities and the exchanging data mode of cooperation tools. The second part of this article illustrates the IFC model. Then we justify the interest shown in a model of cooperative design used for defining a design-aided tool, to deduce advantages and limits of the "Virtual Cooperative Project".

Keywords: Cooperation model, cooperative work design, project management, digital mock-up

1. Introduction

Architecture design is by nature an integrative discipline, drawing upon a wealth of knowledge. It has a strong tradition of interpreting its results not by scientific metric knowledge but through self-referential validation [1]. In fact, an act of design is a designer's interaction in a group of designers. Points of view are often shared between contributors, and decisions about different project aspects are submitted for common approbation. The global organization of the design process allows actors to develop and to prescribe tools and methods improving design. Most of these tools are unsuitable because they don't sufficiently take into account the cooperative dimension and the implicit nature of building designer work [2]. It does not enable them to treat all the semantics of the works especially the one relative to cooperative design (difficulties in tracking actor's work, lack of all the required information, coordination problems, etc). So, in this

paper, our objective is to define a tool that must help designers to obtain maximum project context data and structure works semantic meaning, which allows good objectivity in decision evaluation. This will be able thanks allowing actors to get reliable data concerning the state of the project in order to determine what the actions to be carried out are.

This paper will briefly review collective typology of building domain activities as well as the data exchanging modes. It will then illustrate one vision of the digital project deduced from the analysis of the IFC object model "Industry Foundation Classes" imported for construction. The aim is to identify the capacity of the current IFC digital mock-up to structure the cooperative design activity. After that we justify the interest shown in a new model of cooperative design where the relational organization of the project and the semantic meaning of works are taken into account. Finally, we use this new model for defining a design-aided tool, to deduce advantages and limits of the “Virtual Cooperative Project”.

2. Cooperative Design in the Building Domain

Design activities correspond to a sharing of a space, which contains common and shared objects. This space is always extended by individual contribution (in cooperation) and by collective contribution (in collaboration). This co-production is structured by actors’ coordination.

2.1 Collective Typology of Building Domain Activities

We differentiate three categories of collective building domain activities:

- Cooperation is defined by acting jointly through a non-structured informal relationship. The rules are invented progressively. The coordination is founded on an implicit mode between the actors.

- Some authors like Dillenbourgh (1995) and Lonchamp (2003) [3,4] explain that collaboration is one elaborate form of cooperation. It consists of teamwork producing common work. It requires a large amount of explicit coordination with precise and hierarchized progress (Table1).

- Coordination allows the group members to articulate each action to design and to realize together collective products. Coordination is the mechanisms through which individuals integrate their productive activities [5]. It interferes either at the moment of the final assembly of the partial contributions in a cooperation setting, or throughout a task realization in a collaboration setting. The coordination organizes and structures the cooperation and the collaboration activities: it is inseparable from either of them. The coordination constitutes the mode by which the collective activity is sure to be efficient.

Table 1: The difference between cooperation and collaboration.

	Cooperation	Collaboration
Work mode	Acting jointly	Working in a team
Objective	Actors have a common objective but don't have a common underlying objective	Actors have a common objective and a common underlying objective
Evaluation method	Actors are evaluated in group	Every actor is evaluated independently
Relation nature	Relations are not definite and are unstructured	Relations are lasting
Activities progress	The rules are invented progressively	Activities' progress is known and hierarchized
Coordination type	Large amount of implicit coordination	Large amount of explicit coordination

The collaboration, cooperation and coordination operations are the basis of group activities. Collaboration is an activity where processes are known and repetitive. On the other hand, every building actor works to carryout underlying tasks, and cooperates to assemble their contributions in a common production using coordination. Design is an important building collective activity of reciprocal prescriptions. In a design project, actors cooperate to achieve a same objective, which can be the production of documents, solutions, comments, etc. Criticism and negotiation represent important decision actions. Because of the implicit character dominating in the building domain, a great number of heterogeneous variables are taken into account to design and to construct. As result of this, actors must cooperate successfully and have assistance to save time and money. Today, actors use more and more tools to assist their work, and technologies to structure their exchanging of data and to manage building project.

2.2 Data Exchanging Modes in the Building Domain

In construction, there are two types of cooperation approaches. The first one is founded on documents and exchange files. It is structured by several data exchange practices: manual management of exchanges (sending disks, maps, etc.), exchanges by electronic Email, exchanges through PDM, cPDM[1], etc. Some of these practices save time and are efficient through big projects, etc. Some others show little trace of sharing and are submitted to precise structuring rules for drawing up documents, etc. The second cooperation approach is based on the use and the manipulation of the semantic meaning of a project. It constitutes an experimental practice

[1] Product Data Management (PDM) is a component of the technologies of data products. This concept covers the set of techniques, methods and tools aiming to communicate, on an electronic support, the product data within a company. CPDM is a cooperative Internet version of the PDM.

which consists of sharing a digital mock-up[2] and modeling building projects with interoperable objects. This practice has not yet shown its efficiency, but is being followed with great interest.

3. IFC Digital Mock-up Model

A large variety of CAD software is proposed in the engineering domain. CAD software is specialized for civil engineering professions and has its own modeling concepts [6]. The data exchange between CAD software is so difficult, due to the heterogeneity of the modeling field. Most of these software solutions are based on proprietary solutions with their specific technical model [7], and model the building with 2D geometry. In this formalism, no semantic information specific to the building objects is modeled. To bridge this gap, the International Alliance of Interoperability has proposed a standard called IFC that specifies object representations for construction projects. Industry foundation classes[3] (IFC) include object specifications, or classes, and provide a useful structure for data-sharing among applications. A door IFC, for example, isn't just a simple collection of lines and geometric primitives recognized as a door; it also has a door's attributes (material specifications, prices, etc.). The adoption of this standard by all the leaders of CAD software allows a better interoperability in the exchanges of information between the various civil engineering professions.

The IFC product model is a universal model for the description of buildings over their complete lifecycle. It has been one of the strongest aims of research and development since the early days of Computer Aided Design in the building industry [8]. In the IFC, we found a "product model" that uses the STEP[4] norm. IAI had adopted many STEP industrial standards, but their building sector adjustment raises some data exchange problems:

- The trace of actor actions: IFC model show tangible blanks about intervention traces and the actor role definitions in the development process of a digital mock-up. Until today, we cannot indicate whether an object has been proposed or validated by an actor (IFC 2.X release) [9].

- The project evolution cycle in digital mock-up: During the design of the different objects making up the project, the IFC model doesn't permit us to assign them the progression levels defining the project evolution. We cannot know if an object is under design, under modification or already validated.

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[2] The digital mock-up is a graphic computer representation, in 3 dimensions, of project works and spaces evolving throughout a life cycle. This representation is partial and reflects a given point of view of an actor. (Ex: the digital mock-up of a climatic engineer, of a structure engineer, etc.)

[3] Industry Foundation Classes are currently the more successful to constitute the shared digital mock-up realization in the building domain. The IFC represent a standard of exchange and sharing of data [10].

[4] Standard for The Exchange of Product data model: are international computer exhaustive descriptions of physical and functional features of any industrial product type during its life cycle.

- Semantic meaning used to design works: In the latter IFC update, we cannot attach to every object its manufacture constraints, its rules for setting up, etc. (Among the set of model attributes, there is no specification about regulation rules, structural characteristics, plastic qualities, etc.)

Thus, IFC model shows lacks relative to the cooperative dimension. This model must takes in account the flexibility of current practices and operating mode of project building: so the structure interest of the all exchanged semantic meaning relative to project works.

4. A Cooperative System Developed According to the Model of the Virtual Cooperative Project

In a design cooperation process, the fact that building actors get reliable data concerning project states, helps them to determine what the actions to be carried out are. When concentrating on the data exchanged during the project design, the works are the main focal point. In the same way, every project work holds some relation with its 'environment': with the actors who designs it, the documents that represent it and the activities that create it. Our objective is to provide actors with a real vision of the design process evolution thanks to a digital project (Figure1).

The digital project constitutes the set of data defining works constituting a building. It is an expanded data representation of the different updates of digital mock-ups during the building's life cycle. This project is created and shared by all building actors (according to right to access) on an Internet platform. Every actor's action on documents and works is traced and linked back to the actor. In a digital project, exchanges are managed and facilitated thank to the use of interoperable standard data. The digital project constitutes a virtual cooperation environment for structuring cooperation and communication activities.

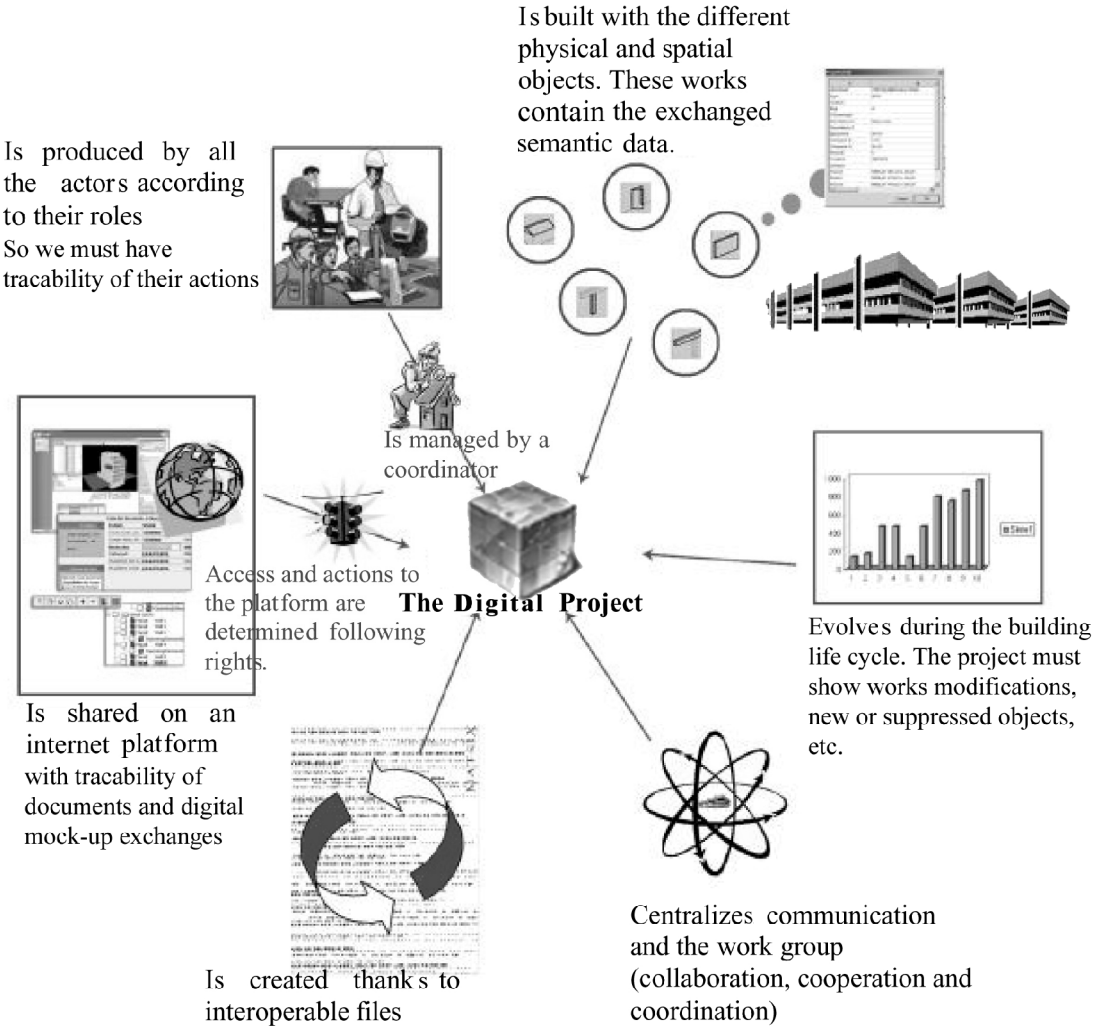

Figure 1: The different dimensions of a Digital Project

4.1 The Meta-model of Cooperation and the Work Model

We propose a cooperation meta-model[5] that allows the taking into account of the existing relations between the elements of a project (actors, activities, documents and objects). The instantiation of the objects allows the definition of the VCP. The Virtual Cooperative Project (VCP) is a project that we have initiated in the co-designing domain, having as a target the definition, the design and the realization of a model able to assist cooperative design in architecture using works (instantiation of objects).

[5] This meta-model is described in MOF 'Meta Object Facility' [11], and used to distinguish concepts, which are common to every design project practice.

A work represents a physical object making up the basic brick of a digital mock-up. This object is characterized by its geometrical and topologic data but also by its semantic meanings. Every work belongs to a class, possesses attributes, relations and is set according relative constraints. A work is the result of coordination activities given during the project and throughout the design cycle until the realization. The works have different design phases and indicate the modifications that they have incurred as being associated with the actors who use and modify them. In the Virtual Cooperative Project, the model of work is structured on 'simple work' (indivisible building work) and 'composed work' (composed of simple works)

The work's semantic meaning represents all data excluding geometrical and topologic data, and is used to define work all along its life cycle. So, in the objective of structuring an aid to the works' design, trying to group maximum data throughout their creation, we have set up a classification table of semantic meaning used to design a work (physical attributes, regulation constraints, structural properties, financial aspect, etc.) However, we distinguish five subtype classes of the 'simple work' following a professional logic taking account of the notion of design evolution during building life cycle: we design structure works first, then those of partition, of equipment, of cladding and finally accessory works. Finally, works maintain four types of relations:

- The relationship between activities and works is distributed in time and shows the works' evolution during the building's life cycle. It is a dynamic relationship. For example: a project generates a digital mock-up; a digital mock-up evolves in a phase; tasks and requests concern works, etc.

- The relationship between actors and works is referential and associative. It indicates actor's interventions on works. It is a dynamic relationship and allows us to distinguish each actor's design work and reflect point of view. For example: an architect creates, modifies, deletes, or validates a work, etc. The study of the relationship between actors and works allows us to identify the relevant semantic meaning related to building works, for each actors' profession. So we have used the classification of works' semantic meaning and the several actors' professions, to set up a table identifying semantic types that interest mainly each actor[6]. This table enables us to develop in Bat'Map a personalized digital mock-up visualization for the different actors.

- The relationship between documents and works is relative to the data specifications. It is a static relationship. For example: a document describes a category of works, a work makes reference to some documents, etc.

- The relationship between works is relative to their design. We distinguish those linked to their development and those linked to their space organization, as a dynamic relationship. We distinguish too those linked to the nature of the relationship between physical parts, as a static relationship. For example: a wall is set on a floor, a beam holds a column, a window is situated in a wall, a digital mock-up evolves in another update, a wall is subdivided in to several walls, etc.

[6] This table is established thanks a statistical survey applied to a several number of actors in four French building analyzed projects.

4.2 The implementation of Bat'Map

To manage a project 'type VCP', which generates a great quantity of information; we have used an interactive navigation interface to develop Bat'Map. This graphic interface constitutes a tool for the cooperative management of a digital project. Bat'Map aims at total structure of the project context using nodes and links. Different types of icons represent the fundamental concepts of a Virtual Cooperative Project (Figure2).

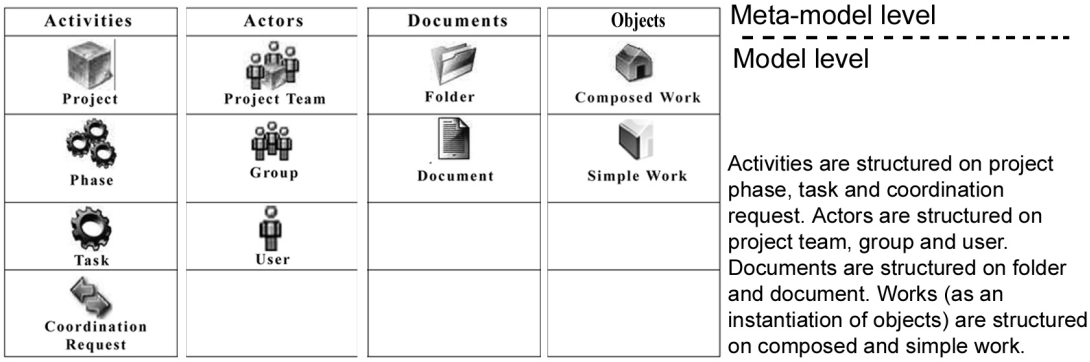

Figure 2: Icons representing concepts of cooperative activities in Bat'Map

On the other hand, Bat'Map is a computer-based system that supports actors engaged in a goal and provides an interface to a shared environment. Bat'Map allows users to initiate a cooperative project environment by identification of actors, activities and documents. When the first update of the digital mock-up is created ('.ifc' type file), a coordinator proceeds to its download from a Bat'Group[7] web platform (Figure 3). The system interprets (thanks to a parser[8]) IFC's data relative to the works; visualizes digital mock-up using a "composed work" node and the works composing it using a "simple work" node. When deposing this first version of the digital mock-up (for example by the architect), the creator will have an automatic link with all works making this digital mock-up.

[7] Bat'Group is a groupware developed in our laboratory CRAI-France. Bat'Group as Bat'Map gives to each actor an adapted vision of the project context, concepts of actors, activities and documents [12].

[8] We have developed a parser, which converts data relative to works contained in the IFC file (written in Express) to compatible data with Bat'Map interface (written in Java)

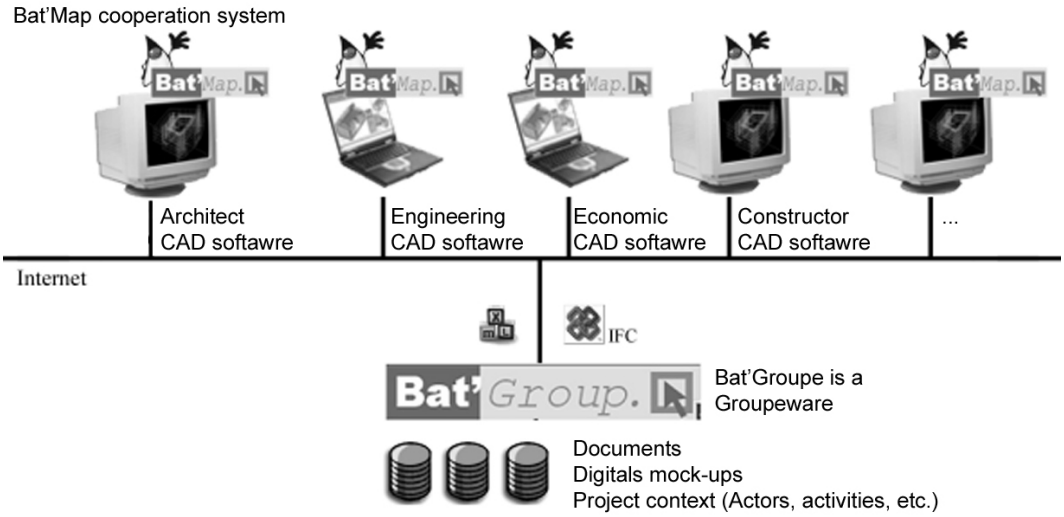

Figure 3: The Bat'Map context use.

When updating digital mock-up, the works evolve. So to identify the new modifications, we adopt 8 states relative to the works. Every work evolves and has different states. A node state represents one work evolution context and is represented by different icons. We have used colors to distinguish cooperation states: inactive object, active object, an object submitting a problem and an approved object. Then, we have used different icon forms to distinguish development states: a suppressed work, a new work, a modified work and a work without change.

Every digital mock-up update, the system proceeds automatically with identifying changes to works, thanks to a comparison between the ".ifc" data. Then, the system proceeds with linking works to the actor (author of the new update) as the one responsible for the suppressed, modified and new works. Works without change are linked to the last update designer, etc. These links between actors and works allow action tracability during the project design.

To facilitate navigation in Bat'Map, we have developed filters and functions allowing an adapted navigation following user needs (to show only works nodes, only actor's nodes, etc.) On the other hand, we have integrated an 'IFC 2.X Release' viewer to allow designers to visualize works. A 3D visualization lets participants move around and in the building. That allows designers to obtain information about the objects that comprised it. Likewise, users can specify in Bat'Map links to other software, in the objective of visualizing text documents, pictures, maps, etc. Finally, we have adapted and developed in Bat'Map works representation and semantic table visualization for each actor's profession.

We conduct two experiments to test the Bat'Map capacity to assist cooperation design in a building project. The script adopted for the experiments describes the design of two buildings (a

wooden salt store[9] and a building extension in France). Actors coordinate themselves in a distributed asynchronous mode. The script steps cover: the building evolution throughout analyzed phases, the cooperation activities solving design problems, the digital mock-up updates, the validation of phases, etc (figure 4).

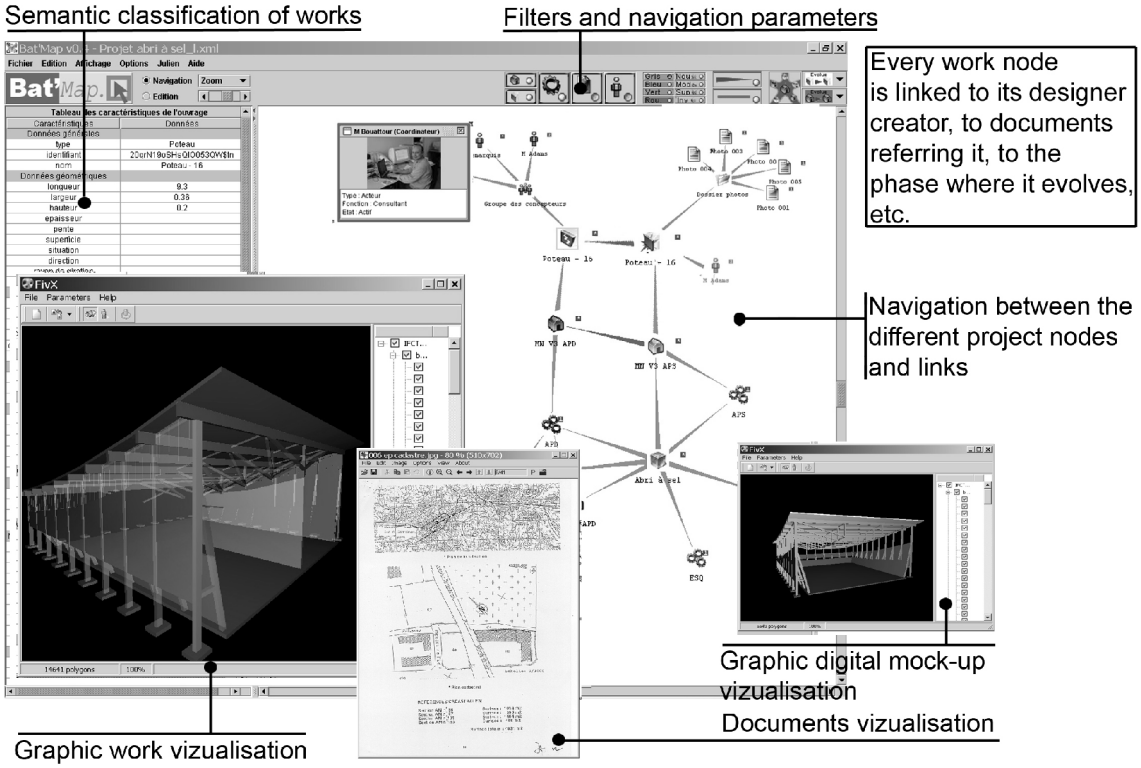

Figure 4: Visualization of the project context of the salt store with Bat'Map.

As a result of experimentations, we notice firstly that the representation of cooperation design context of a building permits a global view of the project: actors, phases, tasks, documents, works and relations between these concepts. Secondly, comparison of several digital mock-up updates during all the phases of the project allows designers to save time when they have to identify changes between updates. Bat'Map allows users to have a clearer view of the building life cycle, and to trace all actors' actions on works and documents. This constitutes a great assistance to the project management. Thirdly, semantic meaning management of works represents a design aid. The fact that designers use all the documents and data relative to a given work, allows for good objectivity in their choices, and enables them to take into account a maximum constraint. Finally, like filter functions, the visualization adapted to actors' professions allows users to have a clearer personalized vision of digital mock-ups and work semantic meaning (figure 5).

[9] Salt store is a building used to protect salt against damp. It is employed for the bulk storage of salt. Salt is sprayed on roads against to protect frost.

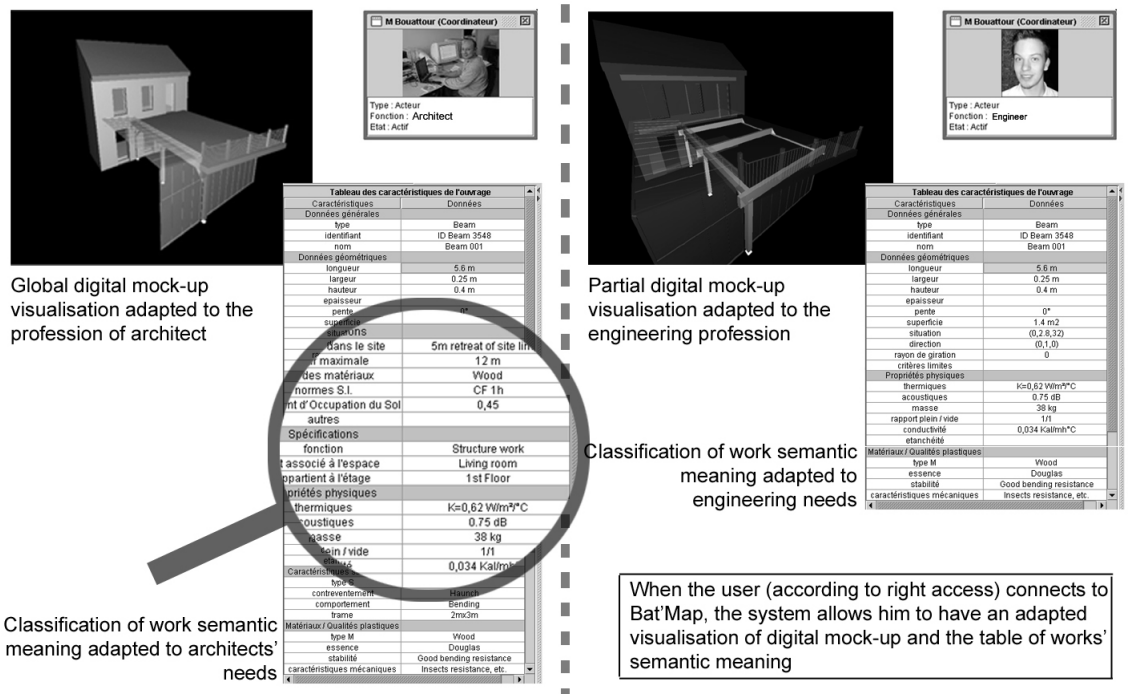

Figure 5: Adapted visualization in Bat'Map.

5. Conclusion

The European Building and Construction industry is to a great extent dominated by small and medium size enterprises. The fragmented nature of this industry necessitates cooperation assistance tools to enable users to design buildings efficiently and manage projects. This paper presents a new approach of cooperation aided-design, which proposes a new data organization of building context, by the representation of the existing relations at same time on the site, and also inside the project. The works are on the basis of Bat'Map (V4.0) development. This cooperation system provides a set of processes, functions and databases placing the IFC at the heart of the project context. The main advantage of using these objects is to provide actors with structured data related to the semantics and the 3D representation of building works.

Bat'Map is developed according to the model of the Virtual Cooperative Project in order to reinforce cooperation and group awareness. This system proposes the structuring of a cooperative project context. It proposes partial views which allow actors to navigate in a virtual environment, to be informed of the progress state of cooperation activity, to study latest digital mock-up updates and changes brought about, etc. The identification of the different states of works allows actors to have a clearer idea of every work and digital mock-up statute. The semantic meaning thus obtained permits actors to adapt their vision of the design evolution and to avoid wrong decisions. The results of the study also show that the visualization of the different digital mock-up updates allows us to have a trace of actors' actions (author, date and modification objects), saves time in the identification of changes and allows us to specify the respective responsibilities linked to modification, creation or forgotten works.

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