INFORMATION SYSTEM TO IMPROVE THE BUILDING PRODUCTION MANAGEMENT

Cooperative work in design and architectural production

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Abstract. Our work is to enable partners of a construction project (building owner, architect, engineer, etc.) to share all the technical data produced and manipulated during the building process, by setting up interfaces for an accessible information system via the internet. Our system would be able to deliver an answer to a user to a particular question asked. The system links databases and allows building partners to access and to manipulate specific information. This paper covers the information structure model based on building construction knowledge and the access to user-relevant information. First, the paper aims to establish the state of the art of the information systems available today in the building construction field. Second, we present the contribution of our research to the description of the building elements (foundations, ramps, stairs, etc.), where information is share by partners who are distant from one another and focused on fields of expertise that are distinct but concurrent. Our system links distributed databases and provides an updated building representation that is being enriched and refined all along the building life cycle. It consists of 3D representations of the building as well as data that are associated with each graphical entity (walls, slabs, beams, etc.).

1. Introduction

The building production is an interdisciplinary activity, implying several disciplines (art, architecture and engineering) and competences (Architect and his partners in the engineering and the construction), who all work on specific aspects of the project (Hamani D., Olive J. and Ameziane F. 2007).
The project integrates constraints and increasingly complex requirements to manage. It answers a regulation in constant evolution and increasing requirements (acoustic, thermal, engineering, etc), whereas the durations of studies, engineering and realization tend to be shortened (figure 1).

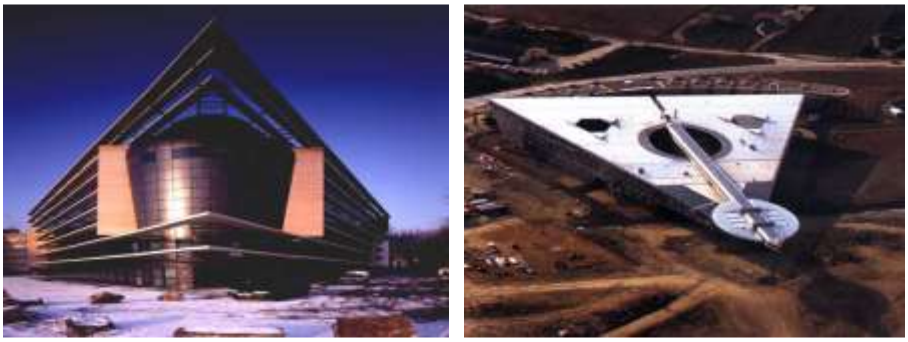

Figure 1. Example of complex building: Palais de Justice, Caen, Architecture Studio (www.architecture-studio.fr)

Today, the actors in a construction project are prosecutors of systems who make it possible to produce the dynamic building descriptions, according to their evolution in the time. Thanks to the new technologies, which enable a better information exchange between all the partners involved, productivity in the building production can be improved (Celink and al., 2001). These tools make it possible to manage a growing of amount information and the actors who are distant from one another, especially for large projects.
Starting from practice observation, the goal of our research program is to share and extract data from the building description and to keep track on all the information changes and updates along the building's life cycle.
To reach these objectives, it is necessary to build an agile information system framework that would be able to support this data processing. In addition, it means that there must be a normative approach to the description of the building elements in order to ease the access to and the re-use of technical solutions.

The question is thus to manage a single information (guaranteeing its integrity), to produce updated documents and to be able to answer to specific queries at any time during the building production process.

2. Data exchange problem in the building production

The building production is complex activity. It faces problems in information management all along the designing, engineering, realization and maintenance stages (Hamani and al., 2003). Many actors (Architect, Engineer, provider, etc.) enrich the project description with their own vocabulary, and generate a lot of documents (figure 2).

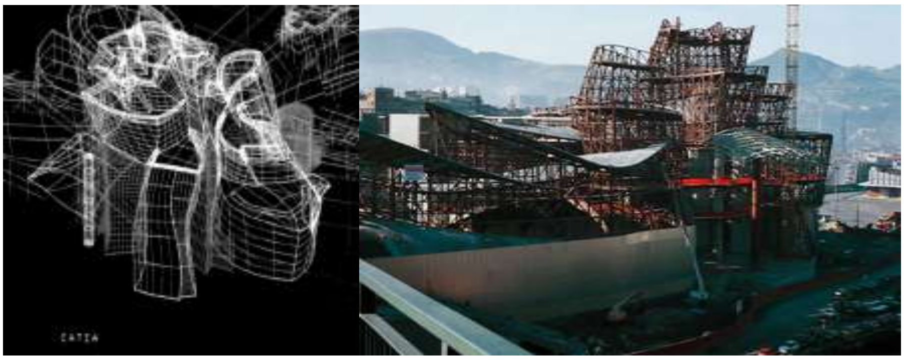

Figure 2. From building design to realization. Wireframe and photos of the Guggenheim Museum in Bilbao designed in 1999 by Frank O. Ghery (www.frankg-gehry.com)

Architectural projects tend to be more complex and integrate a growing number of regulation requirements and constraints:

- User conveniences (accessibility, acoustic and thermal conveniences, etc.).
- Construction (paraseismic properties, complex cost management, etc.).
- Implementation (product selection, technical regulations, reduced construction duration).
- Management of data generated by a growing number of partners with specific points of view.

The data manipulated by partners who collaborate in raising the building is often compiled into professional systems and cannot be re-used by the other users. The data is transformed through these systems and the added value cannot be understood (Hamani D. and Ameziane F., 2003). The problem of data exchange between heterogeneous CAD applications produces small or unsuccessful file exchange formats: DXF, IGES, SET, VDA, CALS, STEP and more recently Industry Foundation Classes (IFC) from the International Alliance for Interoperability (Poyet P., 2002). It is probably the most spectacular one, because it links the major CAD system firms, many CAD users and institutional partners (Figure 3).

Now a day, specific problems of building CAD applications are:

- To develop their low potential to work with a set of not-completely defined data.
- To manage the multiple-meaning of the data during the design process.

▪ To use a terminology that reflects the different building know-hows.

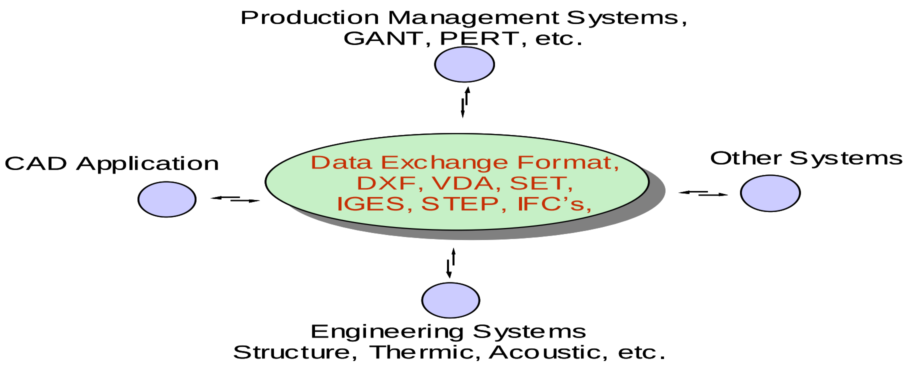

Figure 3. Data Representation Formats in the Building Production (Hamani D.)

For several years, the answer to the data exchange between CAD systems brought different propositions of data representation formats. Many research programs focus on building information management through their life cycle. French research projects (SUC, MOB, GSD, SIGMA, etc.) and international projects (COMBINE, ATLAS, RATAS, STEP, lAI, etc.) consider that there is a strong analogy between the architectural and the industrial field. These various research works feature two major trends in the way to describe a building. Some focus on the building construction works, other research programs focus on the process description that leads to the construction of the building.

However, these tools do not provide real building models offering an effective and comprehensive structure simulation (Hamani D. and al., 2004) as meant in the building construction field, a model that would enable building evolution or use assessment. The results of these works were used to develop our information system.

3. The online project management tools

Today, online project management tools improve collaborative work and ensure project information continuity over the entire project's life cycle[4]. With the introduction of information technology, the data exchange improves between the different partners, which help to improve the building productivity of the construction. These new technologies are used in the building construction to manage architectural projects (Lasserre S., 2004).

[4] The company BuildOnline, 1998, Paris, France.

They are referred to technical data management systems and computer-aided project management tools. Each actor is given the opportunity to carry out its mission with quality and efficiency. These tools allow:

- Managing the Engineering and designing office's production.
- Sharing and exchanging the information in a single model.
- Updating the documents and approval, and follow-up of each new version.
- Controlling the financial information during the maintenance phase.

3.1 TECHNICAL DATA MANAGEMENT SYSTEMS (TDMS)

The TDMS is an electronic system, which makes it possible to manage and control information, concerning objects during all their life cycle through the application of software and the actors (Tollenaere M., 1998) that use these tools. The TDMS is interested in the technical objects and requires a data secure stocking, a data structure, technical objects and workflow. The figure 4 presents the TDMS architecture.

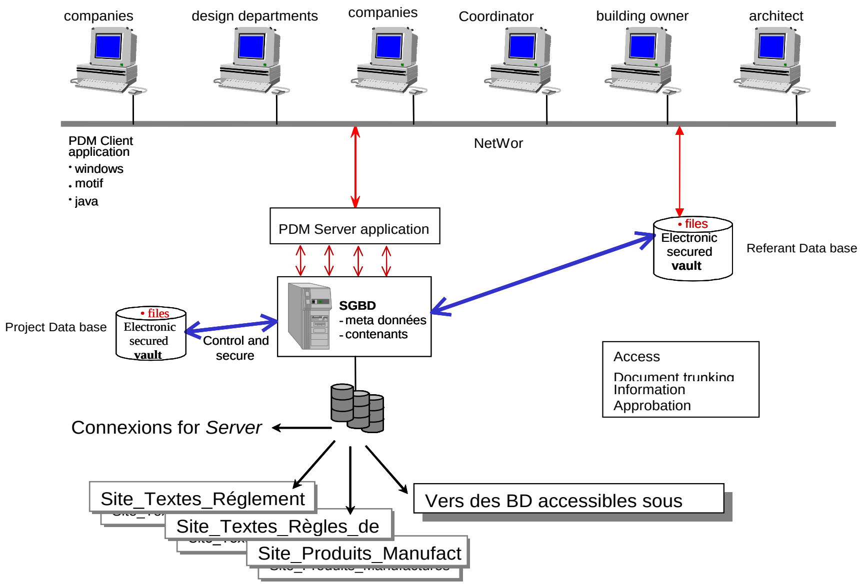

Figure 4. Technical data management systems architecture (Hamani D.)

The principle of these tools is to lean on an object or relational data base, as support for the technical information system. The access to this information is controlled by the data base management systems (DBMS). The support on a data base allows as assuring a level of static data coherence in term of version.

Using a central server each partner (control offices, building owner, etc.), can exchange the documents that are specific to his mission with other partners. The main issue faced by the construction and the building maintenance and management partners today is being able to access, handle and manage all the information related to an operation.

3.2. THE COMPUTER AIDED PROJECT MANAGEMENT TOOLS (CAPM)

The CAPM tools are a solution making it possible to produce file share, validate documents and control the project life cycle. This modular system is built around a core structure that can be parameterized according to the type of building concerned and the main characteristics of the project. It includes office systems and technical applications for document management, so as data consistency, security and availability are guaranteed.
The structuring informatics, used by these systems, is based on an architecture organized in three columns as it is indicated in the figure 5.

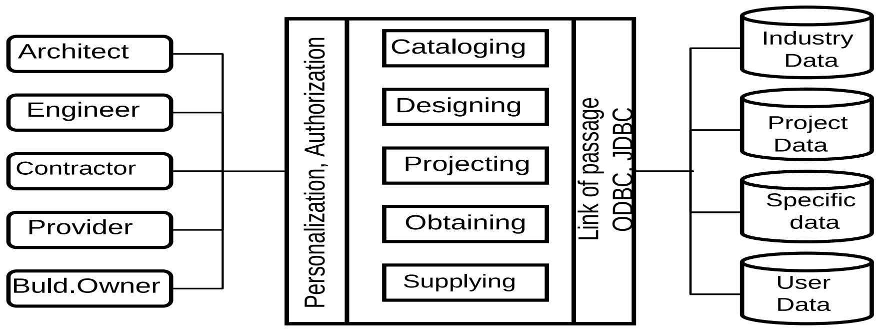

Figure 5. Computer-aided project management tools structure (Hamani D.)

1. The first column provides the graphic interface. The various actors of the building construction can produce and exchange the information via this specific interface. According to the actor, one or more applications can be consulted. For example, a contractor can download documents but he cannot modify diagrams or drawings.
2. The second column contains the technical applications, including manufactured works, catalogues, design software and technical data management tools. The majority of the applications need only one standard Web browser to function. With some applications, such as CAD tools, the software is downloaded and installed on the customer system.
3. The third column represents the data, which is divided into 4 categories:

- Industrial data which is publicly accessible and contains information on manufactured products, providers and contractors.
- Architectural project data, which is accessible by users and contains construction schedules, technical diagrams, textual documents and plans.
- Project data, which includes all information on a particular building such as plans, financing budgets and maintenance programs.
- User data, which contains all information on the users such as the contact information, preferences and rights of access.

4. Communication and CAD Tools research project

In the continuity of the research project, developed at the GAMSAU[5] research center [www.gamsau.archi.fr], the "Communication and CAD tools" project, is focused on the evolution of the building description along its life cycle. This project structured information into a conceptual schema of data matching the knowledge fields of architectural design (Ameziane F., 1998) (Lasserre S., 2004) (Hamani D. and al., 2003). This schema allows as to build a coherent group of entities in a Data Base Management System, from which a collaborative work can be set up. During this activity, each partner can get the building representation (aggregate views of data) he needs to complete his report. This project was led by the following hypotheses:

- The knowledge environment of the building construction area is distributed, but it can be accessed to through a network.
- A building may be described by a series of construction works and the spaces it contains; this is from the construction economist's stand point.
- This description may grow step by step, and every partner can access it.
- We consider that a 3D CAD model was elaborated just before the engineering stage. It seems to be the best media to support the finalization of the building project description.

To answer these hypotheses, we produced a conceptual data diagram that describes the building with the construction works it is composed of. Under a generic class of « Building_Entity » organize all the objects that are part of the construction of a building in a hierarchic set of sub-classes. Each of them is composed of attributes (product specifications) and methods (knowledge relative to a specific product).

The "Communication and CAD tools" system support collaborative work, ensure data continuity through all parties and keep track of design history. We note that once the building has been built, its owner may legally request all the information compiled through the stages. During the operating stage

[5] GAMSAU: Research Group Applying Scientific Methods to Architecture and Urbanism.

of the building, he needs to look after construction works maintenance and sometimes find who is responsible for defects in the building.

5. Information system to improve cooperative work in the architectural production

The evolution of the project management systems presented above offers solutions to the main issues:

- How to deal with multiple-source data?
- How to manage incomplete and changing data?
- How to distribute the data to all the partners involved in the building construction project?

Our work originates from the results of previous projects we have dealt with, that are part of the «product/process model» research programs. It aims at providing an infrastructure that brings together, and promote cooperation between actors. This information system is initiated during the engineering stage, allow enhancement of the data through the execution stage, and will support the owner when the building is in maintenance.

We are answering to the problem of information continuity and fragmentation by sharing a unique data model amongst all parties involved into the building construction processes. Our work was led by the following assumptions:

- Pluridisciplinary and flexible teams: The building construction is a collaborative activity involving several fields of expertise as well as methods and tools shared among its actors.
- Description of the building by work: In a construction project, the first question to answer is "what" is going to be built. This "what" is defined through a system technical flow chart? There are many examples of projects: building a house, manufacturing a car, a tunnel, or producing a data-processing application. Each box describes in a structured and arborescent way the solutions to be produced. The boxes are coded analytically.
- Description of the building by task: It is also necessary to define the types of activities related to each technical solution offered. This is the "how", called the HTS (Hierarchical Structure of Work). This level determines the project structure, which is organized according to the way the works will be carried out.

The objective is to devise a conceptual data model (figure 6) for the "Construction Work" (walls, partitions, floors, etc.) and to control the validity of information in real time. The main goal of our work is to complement the central database initiated in the «Communication and CAD tools» program.

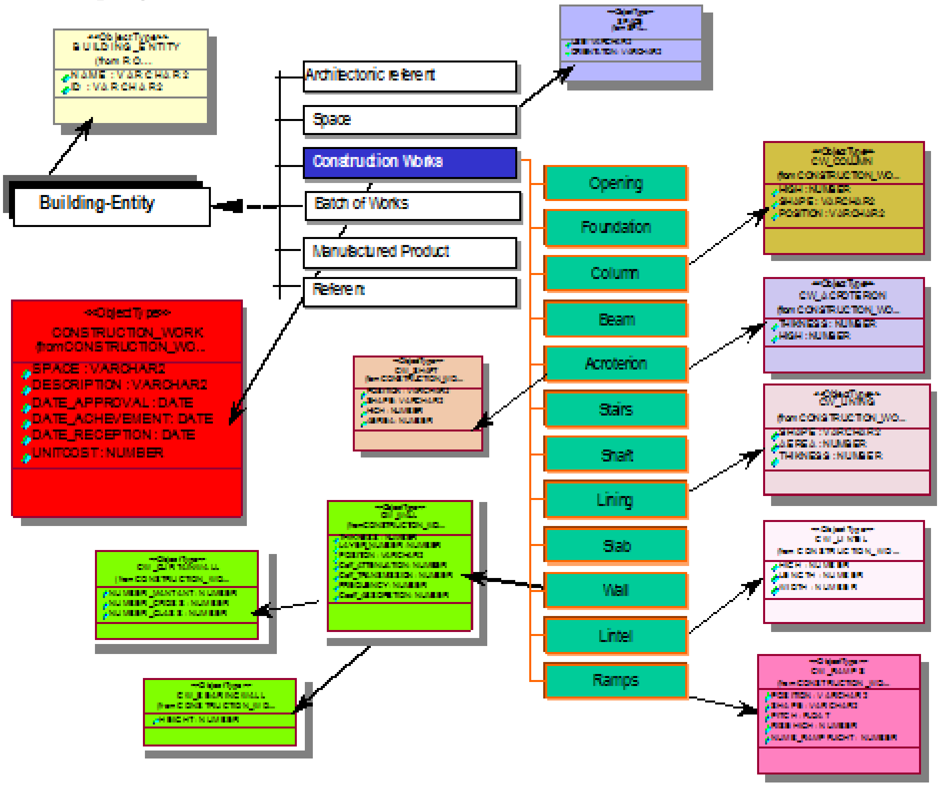

Figure 6. A more detailed Construction_Works description - Overview of main classes (Hamani D.)

To answer these assumptions, we produced a conceptual data diagram which describes the building through the "Construction Work" it is composed of (Wall, Openings, Slabs, etc.). It consists of a generic class "BuildingEntity" and a set of branches that represents a specific domain of the building construction process.

We can see in the figure 7, it will be able to describe building elements like "wall", by its attributes of which some, according to their level of general information, could come from the class "Construction Work". A wall can be described by: a single identifier (ID) which guarantees its uniqueness, and allows memorizing its successive modifications, a position which can specify spaces of which it forms part, a height, a cost, etc.

In the long run, this conceptual data model shall be used to experiment a Supply Chain Management tool for the building construction industry. Its purpose will be to improve the performance of the various actors of the building production in all phases and situations: on the building site, in the management, operation or maintenance of the built work.

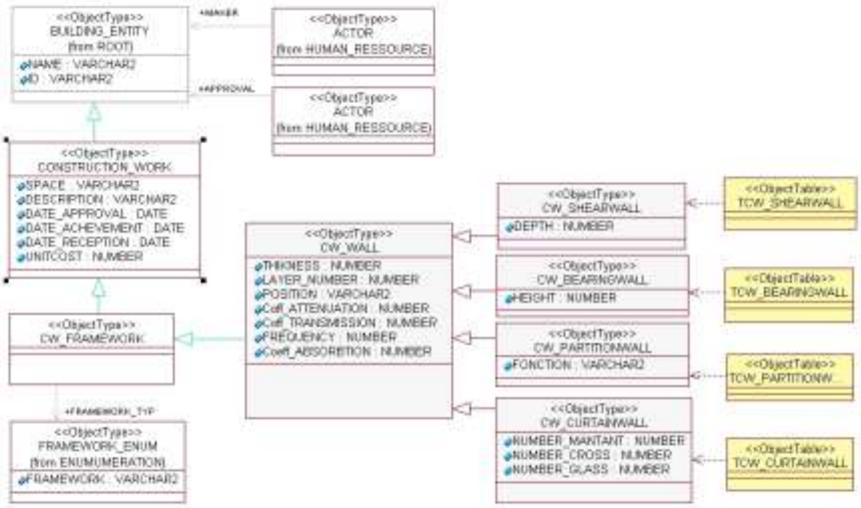

Figure 7. Description of "wall" - Overview of main classes (Hamani D.)

We are implementing this conceptual schema into an Oracle 9i object-relational database. For every building construction project, a new database instance is created. Successive 3D representations of "Construction_Works" can be stored, as well as the linked documents that complement their description. The data can be accessed from a solid and parametric CAD system (Architectural Desktop by Autodesk Inc.) or a web browser.

5.1 PROFESSIONAL APPROACHES

We have seen that it is necessary to take the choices and the decisions of the partners into account by integrating their knowledge during elaboration processes. They also need to be able to make specific queries into the building database and to get a personal and updated representation of the building. To answer a cooperative context, we have based this sub-system on a web environment that allows managing good concurrent access. UML language is a method that enables the structuring of a project, which leads to a conceptual data model. Thanks to this model, the information can be represented in an understandable way and the information system can be described statically, using the object tables and associations. This model objects can be divided, with no need for any other modeling or programming language. It has been created so as to support object concepts analysis. We use Rational Pink from Rational Software. This software works on all platforms, and enables "object tables" to be modeled in conjunction with object tables from our Oracle database. Figure 8, shows the interfaces of tools, called "Rational Rose Software".

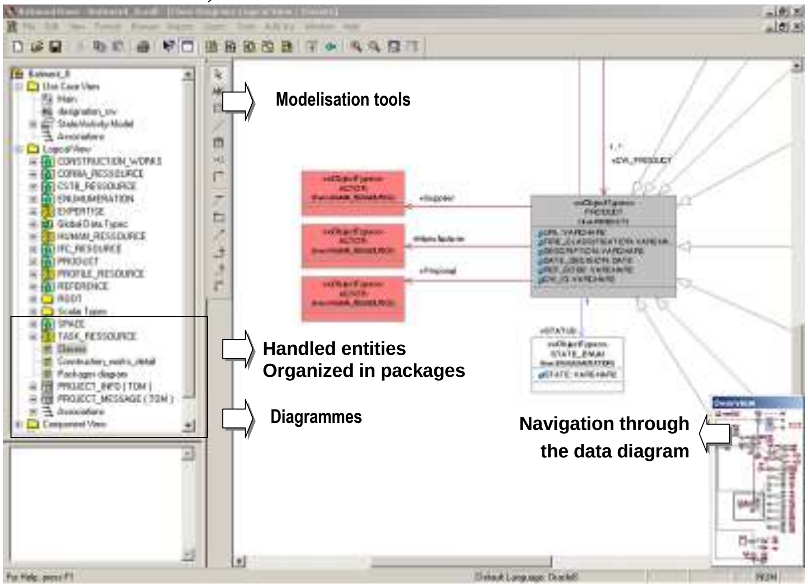

Figure 8. View of the interfaces "Rational Rose Software" (Hamani D.)

Oracle 9i Application Server has been chosen for object technology support and database administration facilities. We are using native Java language and the Java Server Pages (JSP) Apache extension.

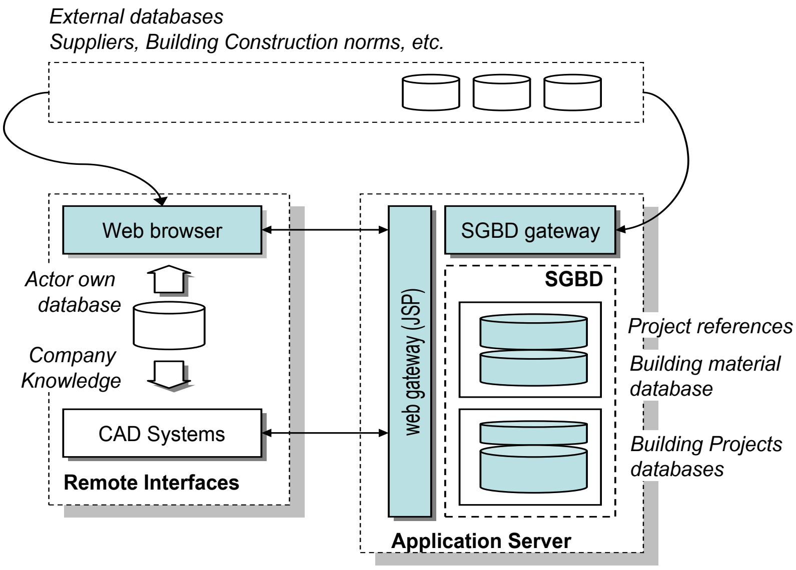

Figure 9. 3-tier System architecture (Hamani D.)

In this context, we implement several Enterprise Java Beans (EJB) to accomplish specific tasks. Each bean generalizes a generic class named "DataRetriever" that can execute any SQL query into Oracle through JDBC thin Driver.

For example, one is managing 3D representations of the building, given an actor role and a phase in the construction process. Another one manage cycles of approvals associated to a construction works and can send alerts to all the actors involved in this process. The next figure shows the architecture of our system.

The data bases are questionable by actors using CAD interfaces which allow them to access the graphical and textual representation maintained in the data bases management system.

The partners also need to be able to make specific queries into the building database and to get a personal and updated representation of the building.

We have been using DWF (Drawing Web Format) from Autodesk Inc. in order to publish vector drawings, and VRML (Virtual Reality Modeling Language) for 3D graphic representations and support alternative query interface. From it, as well as from a tree representation, we can retrieve extra text descriptions of the building entities.

We found good opportunities in this ASCII format, especially to compute nodes in a server context. To do so we are using the CyberVRML97 for Java API (Lasserre S., 2003) that we have extended with new nodes such as Flash movie texture node. To easily maintain and update our information system, we found a good response in the powerful Lotus Notes client from Lotus Inc.

5.2 PROFESSIONAL PROFILES

The architect being the actual database owner is responsible for coordinating the inputs from all the actors and updating the database, in order to provide the users with the latest and most accurate view of the building.

We have worked on electronic representation of the files created during the design and engineering stages. It comes with personal information associated with a professional profile (figure 10).

Each actor is able to customize his default profile, from the rights given by an upper manager. He can select the data he wants to screen on the next queries, as well as construction works graphic representations.

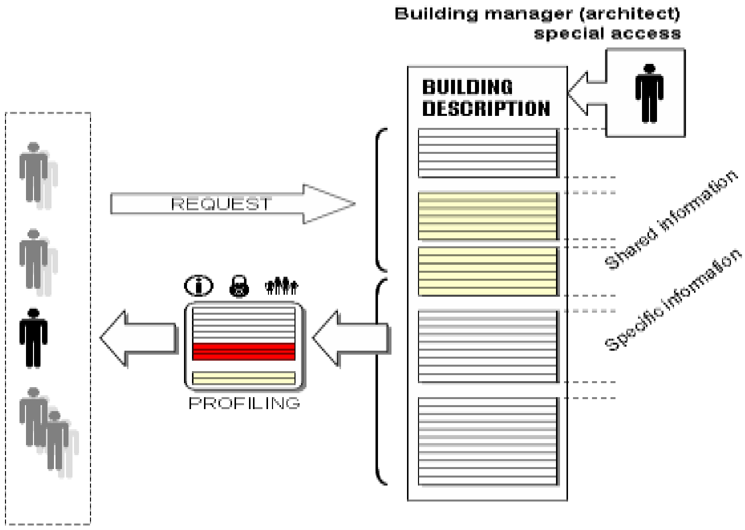

Figure 10. The multi-actors aspect: specific information's for each actor (Hamani D.)

We also propose to put the emphasis on an actor's dynamic profile. It may evolve during the building processes, because his given role may change. Consequently, we take into account this feature and let someone above in the hierarchy of roles update the access strategies.

5.3 PROFESSIONAL REPRESENTATION OF DATA

We give a simple representation of building for each partner. The content of these documents depends on the partner's need. So, we must be able to filter the entire pieces of information in order to deliver a specific answer to a particular partner request.
By anticipation of the products descriptions we can access today through the network, the objective is to demonstrate the specifications of a construction work may be extracted from an exhaustive set of information which the use depends on professional needs. This goal is very important, because answering to the multiple-expertise problem in a building context means we must be able to give a « real time » representation of the building for an actor. This representation is strictly made up of the information's he needs to achieve his expert's report

5.4. A PROTOTYPE APPLICATION

5.4.1. Internet-based service prototypes

In the building communication process, graphic drawings are the most used media because they are the only one that partners of a construction project

have in common. We want to increase interactivity by using them as interfaces to point directly out spaces or construction works. Each space comes as a dynamic 3D file that depends on the selected graphical entities. This interactive 3D representation uses VRML computed on server side, according to the profile.
The figure 11 shows the system status at the end of a query. Once the actor (e.g. Structure Engineer) has logged in, he gets his personal profile with an interactive 3D space representation.

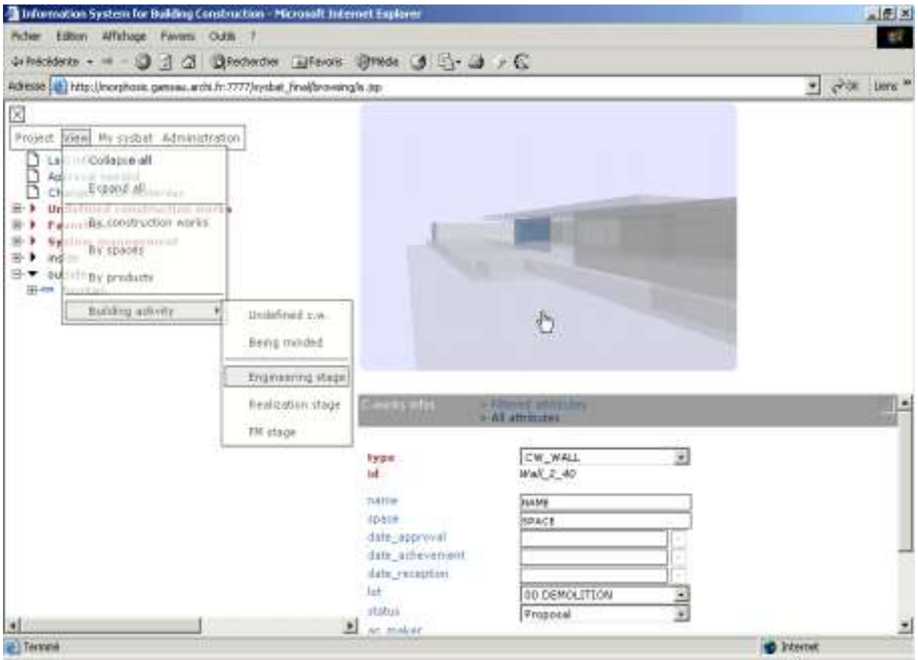

Figure 11. Graphic and Text interfaces (Lasserre S., 2004)

He may use it to select a specific construction work for which he gets a detailed description with all the corresponding attributes on a separate frame. Since we are storing design changes (design history) and managing building activities tasks, we provide enhanced 3D views ("static views") of the building's life cycle. To do so, we set 3D rendering method according to building entities status. The following figure 12 shows the system status at the end of a query. Once the end user (e.g. the architect) has logged in, he gets his personal profile with an interactive 3D space representation. He may use it to select a specific construction work for which he gets a detailed description with all the corresponding attributes on a separate frame. We can see a list of construction works the selected space is composed of as well as attributes of a particular one (ceiling) and a 3D space representation of a structure engineer profile (in this case structure entities are the only one to be shown according to the selected profile).

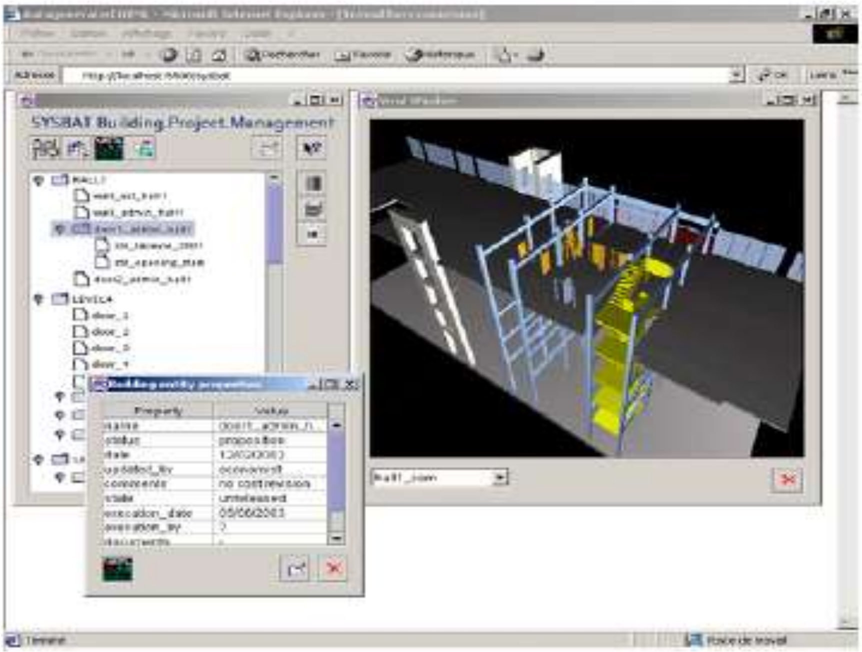

Figure 12. System status at the end of a query (Lasserre S., 2004)

5.4.2. CAD application prototypes

Each space comes as a dynamic 3D file that depends on the selected graphical entities. In that prospect, we represent the set of objects manipulated in the description, in a computerized environment by coupling any ODBC data source (mapped according to our building data schema) with a solid and parametric CAD system (Mechanical Desktop by Autodesk Inc.) and the Internet. This environment allows the users to maintain the building description through its data diagram which needs to be frequently updated because no real normative project has been elaborated yet.
The figure 13 shows the system status at the end of a query. Once the end user (for example the architect) has logged in, he gets his personal profile with an interactive 3D space representation. He may use it to select a specific construction work for which he gets a detailed description with all the corresponding attributes on a separate frame. The figure 14 shows a list of construction works the selected space is composed of (Outside), as well as the attributes of a particular one (Wall). This database is attached to the

architectural project in order to complement its morphologic description with the textual data that usually characterizes a construction work.

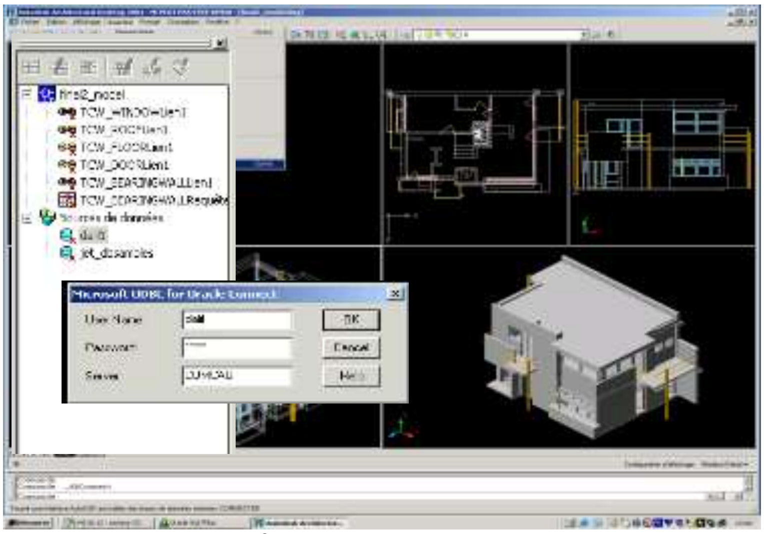

Figure13. The consultation interface by coupling ODBC data source with parametric CAD systems (Hamani D.,)

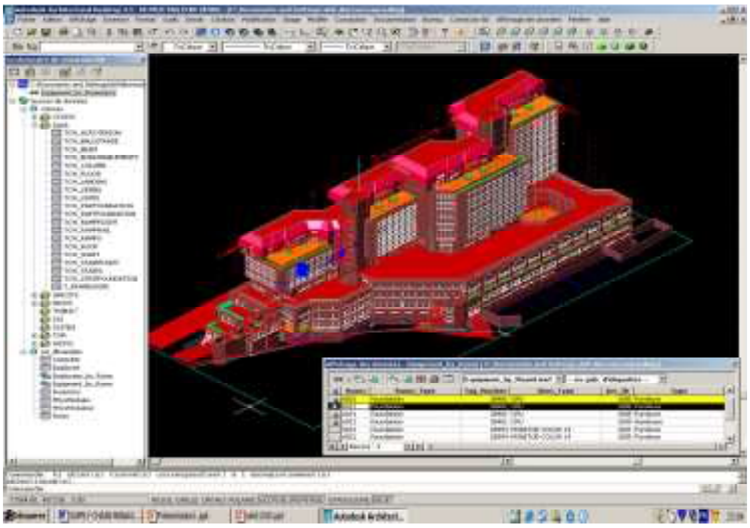

Figure 14. Development of a bond between data base and 3d models (Hamani D.,)

6. Conclusion and perspectives

As in industrial production, many researches are being carried out in the building production sector to improve the communication between the various partners and actors of a project. Whereas most of the recent building information management tools are dedicated to the production and update of technical documents (Bentley Systems Viecon, Constructeo Projecteo, etc.), our system is based on a building construction knowledge approach. It tends to ease the process of the building production by keeping design changes and ensuring information continuity from the beginning of the project.

Our work has been focused on the building product model. It aims to:

- Ensure data circulation between distant partners.
- Be able to share a common description diagram in a Data Base Management System environment.
- Manipulate heterogeneous documents (texts, drawings, multimedia files, etc.) in an efficient manner.
- Help the users by developing decision support systems.

Our next objective is now to extend this system to the realization stages and operating phases, also integrating the building processes models. It aims to set up a technical data management system that would allow the partners of a given construction project to access the available project information from the building site. It would be then possible to take into account the evolutions resulting from the works implementation context and to improve effectiveness and efficiency in this field.

This "project modeling", oriented model, will make it possible to identify the various tasks related to the work completion process, to issue building or work completion schedules and to calculate the resources and cost for each phase. This specific question is of high interest to the building managers as they consider these future tools a way to reach true traceability of the works and the decisions they are based on.

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