

# Active3D: Vector of collaboration, between sharing and data exchange

**Christophe Cruz**

**Christophe Nicolle**

Laboratoire Le2i, UMR CNRS 5158,  
Université de Bourgogne,  
BP 47870, 21078 Dijon Cedex – France  
christophe.cruz@u-bourgogne.fr, cnicolle@u-bourgogne.fr

**ABSTRACT.** This paper presents a new method to structure building information with semantic and 3D. On this method the web platform Active3D-Build was developed. The kernel of this system, composed of information management processes and information sharing processes, is based on IFC files. These files allow us to structure geometric and semantic data. Moreover, these files are used as a structure for interoperability between CAD software.

**KEYWORDS:** digital mock-up, collaboration, interoperability, CAD, virtual reality, IFC

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## 1 Introduction

Decisions taken during the conception phases in huge architectural projects influence a lot the cost and the schedule of the building construction. To ease this decision-making, many mock-ups have been used as a project prototype. This prototyping is useful to test and to improve the conception of projects. Nowadays, collaborative sites that appear on the Web greatly improve the flexibility of the framework's actors of a distant project [01, 02, 03]. Digital mock-ups are used to represent future 3D elements of the final product. The use of digital mock-ups is known to be highly used in architecture. Indeed the visualization of the future buildings in 3D by architects and engineers is a way to facilitate the testing of the choices, the scheduling of costs and process, and the completion dates. In the architecture each type of activities has developed tools for special prototyping: Structural analysis, thermal and fluidic networks, etc. Unfortunately, this development is completely chaotic. Sometimes existing tools in the same type of activity cannot exchange information. Moreover, information stored by tools is in most cases bound by a set of files that contain only geometrical descriptions of the building. Not every actor of a project has necessarily the same knowledge as the other actors to understand and to interpret information. Thus, the collaboration between the actors as well as the data interoperability seems to be difficult to evolve without a

new kind of tool. The following section presents two examples of platform using digital mock-up for the handling of the conception data. This section presents also the problematic of structuring and storing data as well as 3D computing optimizations. Section three presents our solution through the presentation of the Active3D platform for the collaboration of the architectural project's actors. Section four presents the Active3D platform as a central point of collaboration with the help of use-cases examples. The last section concludes on the work being undertaken.

## 2 Sharing and exchange of information

The collaborative work between distant actors on the same project improves the conception of a prototype by reducing the time between each update. A lot of CAD tools were modified to allow virtual prototyping of a digital mock-up from plans and independently of specific project requirements. Unfortunately, most of these solutions do not join together the essential capabilities of interaction and collaboration for the completion of an engineer project. To avoid this problem many projects were suggested. The project Cavalcade [04] is based on a distributed architecture, allowing several distant teams to collaborate on a conception, to test, to validate and to exchange documents. Cavalcade provides a visual system of 3D visualization. Contrary to classical ideas on simulation tools, the virtual representation of a prototype concerns

only the visual aspect of attributes of which the objects of the building are composed. These attributes are functions like “is a part of a subsystem” and documents like technical files or a Web links. The 3D model becomes then a visual interface of information requests. Cavalcade aims to manage conception data. To exchange the models created with the help of CAD software, the developers of this software use specific format files for their requirements. The whole of files that forms the conception of the project constitutes the digital mock-up. The 3D model of the conception object is generally integrated in this mock-up and a set of information allows to manage the project by itself.

Starting from the Saxo and 406 projects, PSA Peugeot Citroën has seen a great augmentation of pieces that are carried out by CAD tools. This fact allows to conclude that the organization of the engineering and design department must be reconsidered. To facilitate the pooling of data on the 206 project, a digital mock-up was installed. With the help of this mock-up all the selection work to extract relevant data from the mass sent by the constructor is almost eliminated. The conception work is then immediately possible from the mock-up. Access to the last updated data avoids expensive errors related to the use of data not up to date. The sharing of conception data is obviously a requirement in order to accelerate the conception cycle. Several problems must be taken into account in the conception of a 3D collaborative platform. The first problem concerns the choice of an information storage structure. The second problem concerns the definition of an optimized 3D interface that allows a flexible and fast handling of stored information.

### 2.1 Structuring and storing

There are two kinds of information storing: files and databases. A file allows to structure a particular kind of information in function of a particular application. In the field of 3D, the file formats are very numerous. Although the principal information of these files is the geometrical representation in 3D of the objects, each kind of file has its own levels of abstraction. The closest model used by video cards is the model with facets. The objects are described by triangular or rectangular faces. The diversity of the models shows that the higher the model level is the lower the size of the data will become. And the computing time to go down to the low level (i.e. the triangular model) from the high level modeling is long. On the other hand, the higher the abstraction level

of information is, the more semantics contains the files. This semantics is an additional knowledge on geometrical information making it possible to re-use in a better way the geometrical file and its definitions. Databases ensure the storage of large quantities of information by structuring and indexing information. Sometimes information is restructured for application requirements which results in a reduction of time to access information. Restructured or not, information in the database is accessible only by a query language. This language makes it possible to extract partial information compared to criteria of selection contrary to the files which are accessible only in block. Thanks to these generic query languages, databases store all information that an information system requires. In general, the databases carry the subjacent semantics of information which they store. Indeed, the structures which receive information model information that they must contain, therefore these structures form metadata on information. The semantics of the metadata specified by the application field is used to request the information system. The databases are thus of primary importance to organize information so that it becomes possible to search for relevant information in a vast set of information such as a file.

### 2.2 3D optimization

Any application has requirements which oscillate between speed execution and quantity of data in memory. The larger information in memory is, the slower the application will become. Certain applications require at the same time a lot of memory and a minimum speed of execution. For instance the computer-aided design often produces complex 3D geometrical models that have a very large size. Thus, the recurring problem in graphical application is the data visualization. Indeed, with the advent of design techniques, the growth of the volume to be computed is largely higher than the increase of the capacity of the graphic material. Consequently, a phase of optimization is necessary. It is located at the data model and at the data themselves. Many techniques of optimization and acceleration for interactive navigation were developed. These include calculations of visibility, geometrical simplification and the image-based representation.

Geometrical simplification: The triangular facets are the most popular graphic primitives. They are managed by the majority of the graphic libraries. The triangular mesh

of a design object is sometimes very complex because it can reach several hundreds of thousands of facets. CAD tools usually generate such objects. Unfortunately, the increase of the data size always exceeds the capacities of the computer. The algorithms of simplification reduce the number of facets of an object according to quality criteria [05, 06]. Research on the simplification of surfaces enjoyed a great popularity during the last decade but these techniques are usually used with other optimization techniques because they do not solve all the problems.

**Occlusion Culling:** The complexity of scene computing is related to the number of objects present in the one concerned. Visibility computing determines if an object is visible according to the observer's point of view and if it is visible then it enters in graphic rendering pipeline. The graphic computing times and the memory space depend on the number of objects constituting the 3D scene [07]. On the one hand, it is obvious that the graphic computing time of a whole building is higher than that of a small apartment. It is simply due to the number of objects that are present in the 3D scene. On the other hand, if the objects hidden by the visible objects do not enter in the computing cycle of the image then the time saved is considerable and thus it is not dependent of the kind of the building.

**Image-based techniques:** These techniques use references of pre-computed images of the 3D scene. The 3D objects are replaced by 2D pictures. These techniques are relatively inexpensive in resource and do not require a specific graphic material. The graphic computing time of an image is independent of the geometrical and physical complexity of the scene that is being rendered. It appears clearly that the rendering based on image-based techniques is extremely useful for its effectiveness with complex scenes [08, 09, 10, 11].

**Coupling of these techniques:** All these techniques were combined successfully for rendering specific data including architectural models [12] and urban models [13]. The GigaWalk project is a rendering system that makes it possible to render CAD projects of more than 10 millions of polygons. The most striking example is the design project « DoubleEagle tanker » made up of more than four gigabytes of data, that is to say 82 million triangles and 127 thousand objects. The rate of calculation is 11 to 50 images per second which allows

to navigate in real time through the digital mock-up after a time of approximately 40 hours pre-calculation [14].

There is, however, no perfect system. Each technique has advantages and disadvantages but certain combinations with precise conditions are very effective. These techniques described previously proved their reliability within a static framework, i.e. the optimized scene is calculated once for several visualizations. In fact, the pre-computing time before the accessibility of the scene can sometimes take several days. The pre-computing of the optimized scenes is the major problem of all these techniques because if the 3D models evolve during this time then the management of the data synchronization must be taken into account. These synchronizations are not always possible because the complete structure of the scene can sometimes change. Other ways must be explored to allow for the visualization of a 3D scene to evolve during this time. Optimizations are always carried out in comparison to the geometry or the topology of the scene. On the one hand, the nature of the geometrical objects was not taken into account for computing optimization. The nature of the objects thus proves to be an undeniable way for research. This nature depends on the scene structuring but if it is limited to geometrical information then only geometrical optimizations are applicable. On the other hand, if information on the nature of the objects is indicated then this information provides a new way of research on the handling of geometrical information and their storage.

### **3 Collaborative Web 3D platform**

Nowadays, the fundamental needs of all the actors in architectural engineering projects relate to a simple tool which allows a coordinated management of the actions carried out in a project. This tool must allow to manage data generated during the life cycle of the project through a 3D visualization of a digital mock-up and must also allow its access to all through a collaborative Web platform. This section presents the ACTIVE3D-Build platform which makes it possible for the actors of a project, geographically dispersed - from the architect to the plumber - to exchange documents directly in a virtual environment centralized during the life cycle of a civil engineering project. A 3D visualization makes it possible for the actors to move around the building that is being designed and to obtain information on the objects. This section is divided into three parts. The first

presents the format used to describe the data. The second part deals with the data structuring. The third part presents the division method and exchange of data.

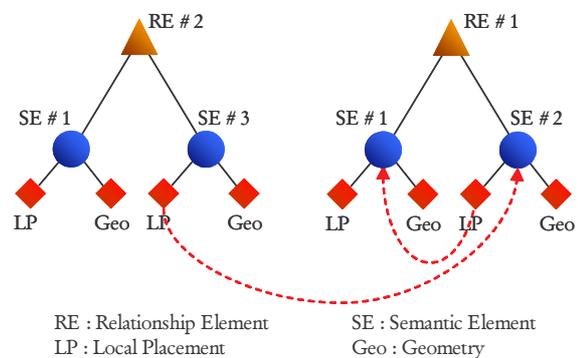
### 3.1 Data format

CAD software used in civil engineering projects models each building element by a set of vectors. In this formalism there is no semantic information on the objects that compose the building. Thus, there is no way to select automatically objects by their nature. To solve these problems the International Alliance for Interoperability (IAI) proposed a standard called IFC (Industrial Foundation Classes – <http://www.iai-international.org/>) which describes the representation of the objects that can be found in an architectural project. The IFC file format is a model which associates trade semantics with 2D/3D geometry for each element constituting the building. The addition of trade semantics makes it possible to limit the redundancies of information because it identifies instantaneously each element that the building is composed of for a faster qualification of the building elements. The basic classes of the IFC include the description of the objects and provide a structure permitting the data interoperability between trade applications. For example, an IFC door is not simply a collection of lines and geometrical primitives identified as a door, but it is recognized such as door by the machine and has attributes corresponding to its nature. The adoption of this format by all the leaders of software CAD solves the problem of the interoperability of information between the various civil engineering professions. Each profession intervenes in the project in a particular context, enriching the plan with its own vocabulary, its own concepts and its own trade objects. At the end of the project, the IFC files corresponding to the building contain all the building elements using a multiple context definition. The IFC files are textual files whose size can reach more than 100 megabytes. Several IFC files can coexist on the same project. For the reasons evoked previously, the choice of this format is thus judicious for the realization of an architectural collaborative platform.

### 3.2 Data structuring

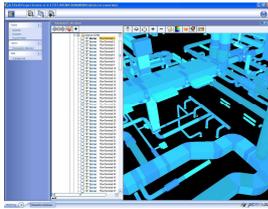
The choice of the IFC format for the data structuring has many advantages but comprises also certain disadvantages. The study of the IFC shows the complexity of the links between the instances of

relational classes and the instances of object classes. On this level there are two types of links between the objects. We call them direct and indirect links. The indirect links are defined by instances of relations, "Relationship Element" (RE: triangles - Figure 1). The direct links are defined by discontinuous red links between the instances of class resources (rhombuses - Figure 1) and an instance of "Semantic Element" classes (SE: circles - Figure 1). These indirect links are relationship elements. The instances of objects in our architecture are semantic elements. The instance resources are the attribute elements like the geometry (Geo) or the local placement (LP) and are structured as hierarchical trees.

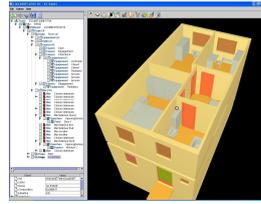


**Figure 1.** Example of direct and indirect links between several semantic elements

These resources are of very diverse nature like the type of materials for a wall or the structural characteristics for a beam. Those are defined in the model IFC but we can also add other types of resource like Word@ documents, requests on Web Services (elements of catalogue's suppliers), etc. These types of resources are added to the IFC via our structuring model of the IFC for the management of electronic documents. The IFC model defines only one type of direct link between two semantic elements. This link is the placement link used for the definition of the local placement between the graphic elements of scene 2D/3D. In the IFC model this link is called "IfcLocalPlacement". The whole local placement link forms a tree which is the graphic tree scene. Thanks to the definition of their semantics, the nature of the elements makes it possible to choose which elements are relevant for the actors of the project. Consequently the elements are extracted from the platform according to the needs.



**Figure 2.** A 3D scene corresponding to the plumbing context



**Figure 3.** A 3D scene corresponding to the architectural context

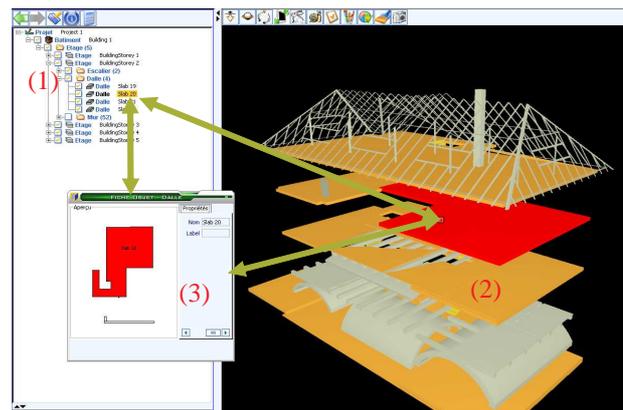
Figure 2 shows a representation of the trade plumbing view of an IFC file. Figure 3 shows a representation of the architectural trade view. These trade views are textual information from which specific documents can be generated or associated (reports, information of management, etc). In the 3D scene all the geometrical forms defined in IFC trees are converted in the triangular model of surface [15]. During this conversion, the 3D objects are associated to a GID. This GID is the general identifier used to identify each trade object of an IFC file. The GID is used to combine 3D visualization with the information stored in the database. Any insertion of new data in any database is referred to by a GID corresponding to an object IFC. All the trees generated by the platform are XML trees. We developed a database schema which takes into account semantics and the 3D aspects of the IFC files. The trees and elements are stored in a relational database and are handled using SQL. Thanks to this database and the GID, all types of information can be combined to a trade object of a 3D scene.

### 3.3 Sharing and data exchange: The ACTIVE3D method

The mechanisms of management and handling of IFC files, like the fusion of two files in one, the partial extraction of data from one file, visualization or storing, must take into account the multiple semantic values of the objects, which depend on the context of use. To achieve this goal, we defined a hierarchical structure of context called contextual view. The solution consists in reducing the complexity of a cyclic multiple-context graph in an acyclic mono-context graph.

Figure 4 presents the 3D scene management system which builds a specific user interface made up of a tree of composure (1), of a 3D scene (2) and of a technical chart (3) on a semantic element of the scene. The navigation between the elements is carried out using

hypermedia links which associate a set of semantic elements to a trade object. In this case the trade object is a semantic element “Slab” (Slab - Figure 4). Certain contextual trees are generated dynamically by the system starting from IFC files. Others can be created specifically by the actors to structure their data according to their own format (starting from an IFC file or starting from existing trees). The principal tree is the geometrical contextual tree which contains the topological relations of the various objects. The resulting 3D scene corresponds to a particular trade view [16]. This view corresponds to the actor trade association. This one is customized by the actor according to his needs, its rights, and the size of the data to be transmitted on the network. Starting from this interface, the actor can update the model while adding, modifying or removing part of the principal tree. The selection can be also carried out through the 3D scene by selecting the 3D objects. The following section shows the services available to the speakers of the project underlining the collaborative aspect of the processes of the platform.



**Figure 4.** Snapshot of the 3D scene management system

## 4 Demonstration of interoperability thanks to IFC

This section shows the use of the ACTIVE3D-Build platform as well as IFC files within the framework of civil engineering projects. In the first part of this section we will see the design phase of a building through actions made by several actors working on different CAD software. The second part of this section presents the technical study phase of the building for the structural and thermal validation of the building being designed.

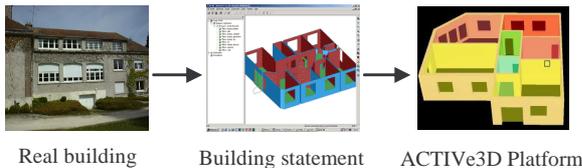
#### 4.1 Phase 1: Conception

The design of building is divided in four phases. The first phase consists of bringing a ground statement of an old building to the platform. The second phase consists in defining an extension to this building. The third phase carries out the extension and the last phase defines the building's floors raised in the first intervention.

##### 4.1.1 Viz'all: A solution for building statement via a pocket PC



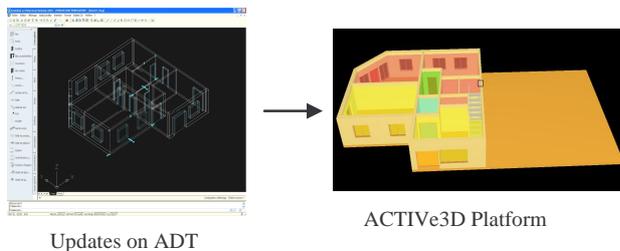
Viz'all® is an automated solution of building statement, associating the use of a laser meter, a pocket PC and software on a pocket PC. The principle consists in tracing by hand the sketch of the room on the touch screen of a pocket PC. After the connection and the deposit of the statement on the ground, the model of the building is updated and is available for all the other actors of the building restoration project. The other actors of the project can now visualize the building starting from the 3D interface of the ACTIVE3D-Build platform.



##### 4.1.2 ADT: Mock-up enrichment



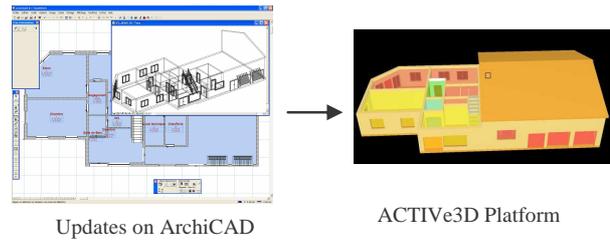
After the deposit of the ground statement, other actors of the project connect themselves to the platform to retrieve this statement and to enrich the mock-up. For this, the architect defines new spaces by using ADT (Autodesk Architectural Desktop). Once the architect has finished his updates on the model concerning the future building extension, he adds these new data to the platform.



##### 4.1.3 ARCHICAD: Mock-up enrichment



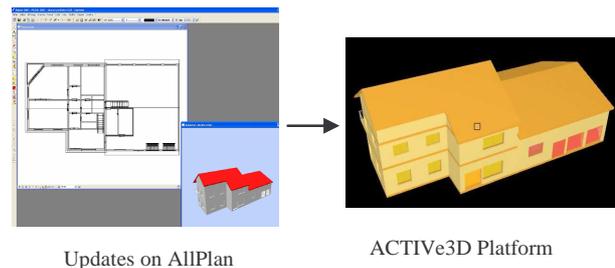
Following the architect's updating of new spaces in the extension of the building, the engineers of the civil engineering connect themselves to the platform to collect the last information. These engineers work on ArchiCAD® from Graphisoft. When they have completed their work of building design, these new data are added to the digital building mock-up that is designed on the ACTIVE3D-Build platform.



##### 4.1.4 ALLPLAN: Importation of file and finalization of the building



The second part of the project on this building is the rehabilitation of the existing building. For that, a team of engineers manages the design of this part. As the other teams do, this one is connected to the platform to extract information concerning the principal building. This team works with the software AllPlan® from Nemetschek Systems Inc. Once the updates have been carried out, the engineers put this new information on the platform.



##### 4.1.5 Assessment

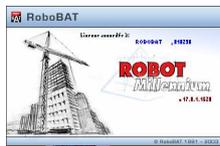
Thanks to the platform, a whole set of actors can exchange information on the building design and this between various types of CAD software. The IFC 2.x standard is used to format the data sent to each actor. All the data flows forward through the ACTIVE3D-Build platform because it allows each actor to have all data up

to date, once they were placed on the server. The effectiveness of this exchange process and the centralization of information has as its result an important time saving because the data exchanges take place on a daily basis in design projects. Moreover, the waiting for data updates can block the work of another team, therefore the access to the up-to-date digital mock-up on the platform makes it possible to resolve these emergencies more quickly.

#### 4.2. Phase 2: Technical studies

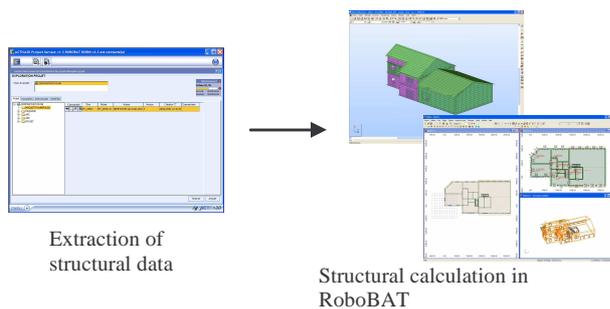
We saw in the previous section that it is possible to add information to the semantic elements of the digital mock-up of the building. This semantic information will be re-used thereafter in the creation processes of new data on the building using calculation software.

##### 4.2.1 Structural calculation



During the design of a building, the structures like the beams and the columns must be validated. Indeed, if the structures are too weak and they do not respect the

standards then the plans must be modified accordingly. RoboBAT is a structure calculation software. This software makes it possible to optimize and validate the structures according to national and European standards about reinforced concrete, wood, steel, aluminum, etc. One of the advantages of this software is that it allows to import IFC data. Consequently, the structural engineering and design departments can validate information of the digital mock-up being designed on the ACTIVE3D-Build platform.

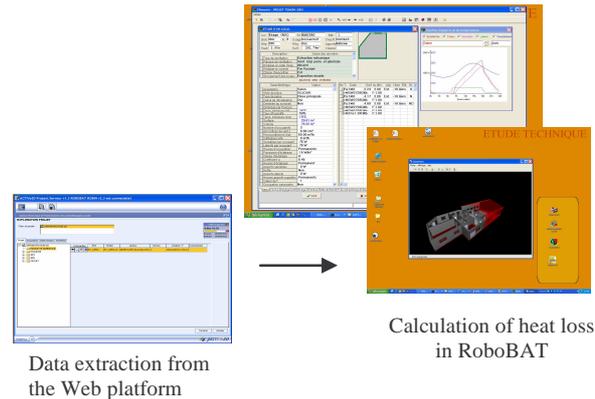


To realize this study, the engineers must connect themselves to the platform and select all the elements concerning the structure. These elements are the walls, the slabs, the beams, etc. For that, they use the definition of the contextual tree "structural analysis".

##### 4.2.2 Thermal calculation



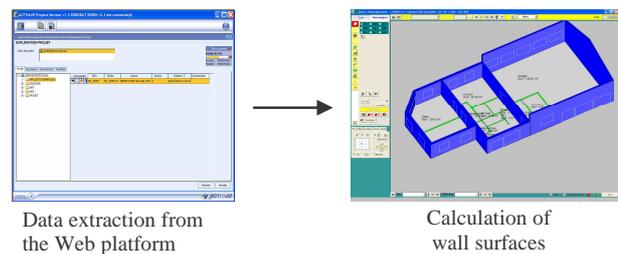
Heat exchange between building spaces have standards for the validation of these exchanges. The thermal module of the software CLIMA-WIN® made by the company "BBS Slama" makes it possible to carry out the calculation of heat loss "Th-D 1991" as well as the lawful coefficients of the buildings according to "ThBât/ThU rules" of 2001. This software imports and exports IFC data which allows to update and to validate the digital mock-up concerning the heat exchange.



##### 4.2.3 Calculation of Bill of Quantities



Windesc® is a tool of bill of quantities from the company ATTIC+ which imports IFC files. This software provides reports/ratios and estimates in connection with surfaces of walls, grounds, etc. This tool is essential when it comes to establishing the revaluation of the cost of the building construction. The reports/ratios and the estimates carried out on the digital mock-up are then added to information concerning the building and the phase of design.



## 5 Conclusion

In this paper we have presented the Active3D method which makes it possible to associate semantics, 3D and documents. This method was adapted to the IFC to

allow the semantic handling of the building components. This handling implies the partial extraction and insertion of building elements in a digital mock-up. This method was implemented as a web platform called ACTIVE3D-Build. The infrastructure of this modular platform is based on a Service Web Architecture developed in JAVA. The module of 3D visualization called "IFC Viewer" was developed using GL4JAVA. The "IFC Viewer" passed certification ISO/PAS 16739 under the direction of the IAI. The Active3D-build platform received the gold medal of the technological innovation to international building exhibition BATIMAT in Paris, November 2003. Currently the research on the platform heads for two directions. The first direction relates to the phase of "statement of plans". We develop a module of 3D acquisition connected with the platform to convert a cloud of points into a set of IFC semantic elements. The second direction relates to the development of an automatic tool of qualification at the data update time on the platform between several participants. A part of this problem is solved by a step which plans the interventions of each actor in the process of conception/construction. Nevertheless the management of the problems of coherence between each phase is not automated and the know-how of the architect and the engineers is always necessary.

## 6 Bibliography

- [01] J. F. Balaguer, S. De Gennaro, *VENUS: A virtual reality project at CERN*. Computer Graphics 30, 4 (Nov. 1996), 40-48.
- [02] D. Aliakseyeu, J. B. Martens, S. Subramanian, M. Vroubel, W. Wesselink, Visual Interaction Platform, In Interact 232-239, Tokyo, Japan, July 2001.
- [03] G. Klinker, A. Dutoit, M. Bauer, J. Bayes, V. Novak, D. Matzke, Fata morgana – a presentation system for product design, In International Symposium on Augmented and Mixed Reality (ISMAR) 2002.
- [04] Cavalcade : <http://vr.c-s.fr/cavalcade/index.html>
- [05] H. Hoppe, *Progressive meshes*, ACM SIGGRAPH 1996, 99-108, ACM SIGGRAPH 1996
- [06] D. Paillot, F. Merienne, J.-P. Frachet, M. Neveu, *Triangulation et simplification de modèles surfaciques application à la visualisation temps réel*, GTMG, Aix en Provence, pp 131-138, mars 2003.
- [07] D. Pearce Partial, A. M. Day, *Visibility for Virtual Reality Applications*, WSCG'2004, February 2-6, 2003, Plzen, Czech Republic.
- [08] M. Levoy and P. Hanrahan, *Light field rendering*, in Computer Graphics, SIGGRAPH 96 Proceedings, 31-42, 1996
- [09] S. J. Gortler, L.-W. He, M. F. Cohen, *Rendering layered depth images*, Technical Report MSTR-TR-97-09, Microsoft Research, March 1997.
- [10] D. Christopoulos, A. Gaitatzes, G. Papaioannou, *Image-Based Techniques for Enhancing Virtual Reality Environments*, 2nd International Workshop on ICT's, Arts and Cultural Heritage, November 2003, Athens, Greece
- [11] W. R. Mark, L. McMillan, G. Bishop. *Post-rendering 3D warping*. In Proceedings of the 1997 Symposium on Interactive 3D Graphics. ACM SIGGRAPH, April 1997.
- [12] T. Funkhouser, S. Teller, C. Sequin, D. Khorramabadi, *The UC Berkeley System for Interactive Visualization of Large Architectural Models*, Presence, the Journal of Virtual Reality and Teleoperators, vol5, nb1, MIT Press(1996), pp.13-44
- [13] P. Wonka, M. Wimmer, F. Sillion, *Instant Visibility*, EG 2001 Proceedings, vol20(3), Blackwell Publishing, A. Chalmers and T.-M. Rhyne, pp. 411-421
- [14] W. V. Baxter III, A. Sud, N. K. Govindaraju, D. Manocha, *GigaWalk: Interactive Walkthrough of Complex Environments*, Eurographics Workshop on Rendering, 2002.
- [15] R. Ronfard, J. Rossignac, *Full-range Approximation of Triangulated Polyhedra*. Computer Graphics Forum 15(3): 67-76 (1996)
- [16] Boon-Hee Kim, Jun Hwang, Young-Chan Kim, *The design of high-level database access method in a Web-based 3D object authoring tool*, The Fourth International Conference on Distributed Communities on the Web, 3-5 April 2002, Sydney, Australia.