Smart Interfaces for New Building Design Process

Hugo Martin, Sylvain Chevallier, Eric Monacelli

Smart Interfaces for New Building Design Process

Hugo Martin
Bouygues Construction SA
78061 Saint-Quentin en Yvelines - France
hug.martin@bouygues-construction.com

Sylvain Chevallier, Eric Monacelli
Versailles Engineering Systems Laboratory (LISV)
University of Versailles Saint-Quentin
78140 Vélizy - France
sylvain.chevallier@uvsq.fr,eric.monacelli@uvsq.fr

***Abstract*—Building information modeling opened new horizons for designing future urban spaces. Logistics and mobility issues are difficult to take into account during the construction process, as they require a precise global vision and the access to information yields by different building departments (architecture, methods, structure...). This contribution proposes a novel approach, based on a collaborative framework, to develop the building model, that is to ensure the quality of logistic and mobility during construction, with a time-efficient methodology.**

***Keywords*-Building Information Modeling; Building Architecture; Data Visualization**

I. Introduction

In construction, virtual reality systems are following a “building before building” approach [1]. Known as Building Information Modeling or BIM, this approach aims to design a virtual model of the construction before actually starting the building phase. Following this approach, systems based on virtual reality allow to interact with these virtual building. Many industries already rely on virtual reality tools for pre-production studies as pointed out by [2]. In construction, virtual reality could help to grasp the full extent of the architectural project, through visual feedback and interactions [3], [4].

Several interaction methods to ease the visual inspection and handling of construction projects have been outlined. The main idea is to assist the BIM engineers in the building conception phase. The main difficulty is related to the tremendous amount of data available in the model: there is too much information to display and each BIM engineer needs only a fraction of the information (electrical, methods, structure, and so on). The challenge is to propose a smart display of the information, depending on the user profile. This contribution describes an ongoing project, proposing a working environment for BIM tools, allowing a better handling of logistic and the mobility during the whole construction process. The novelty of this approach is to rely on a profile-based approach for the conception of all the BIM tools. This project, called Arcas, helps to demonstrate the interest of virtual reality tools for BIM in a real production environment.

This paper first review the literature and the need for immersion approaches in virtual reality for BIM processes. The Arcas project is then described and the integration in a professional workflow is highlighted. Lastly, the experimental part focus on the analysis of the on-site activities and the evaluation of the profile-based approach.

II. On the importance of the conception for BIM

Designing a complete construction project is hard to manage. During the implementation stage, the site supervisor is confronted with numerous design problems. The BIM proposes a new design approach: the design is based on a 3D mock up of the project where all architects and engineers collaborate. The work of [5] shows that the more developed an architectural project is, the more difficult it is to change. From this observation, the BIM introduces a new set of tools to inspect and fix design problems in a virtual environment. It opens up new possibilities for virtual construction reviews, with the possible exchanges between construction actors. The aim is to design a complete project in a virtual world and to avoid artifacts during the study, e.g. water pipes going through electrical cables.

These problems raise the question if virtual reviews are sufficient. Software solutions propose the inspection of BIM models. For example, we can cite Naviswork from Autodesk [6]. Software products try to simulate a real construction review, putting the user in immersion. All the interface is based through a standard screen and the interaction is inspired by video games. However, a large number of design problems still exists, construction engineers are not enough assisted during the interaction with the model.

The virtual reality replicates an environment, real or imagined, and simulates a user’s physical presence and environment to allow for user interaction [7]. Virtual reality could immerse construction engineers into the BIM model of the project. This paper describes a set-up of a virtual room named Arcas which proposes a complete methodology to assist and immerse construction actors during the design of architectural projects.

III. The Arcas Room

Arcas room is the direct follow up of the Callisto project, an immersive room integrating a set of software tools and interaction interfaces [8]. The result is a large immersive room located in Paris, France, at “la Cité des Sciences”, available for general public with the objective to demonstrate the extend of the virtual reality possibilities.

Arcas room is designed for an industrial use and is located in the head office of Bouygues Construction, a major actor of the international construction industry. The set-up is composed by several systems which assist directly construction actors. It integrates various solutions to visualize and to interact with the construction virtual mock-up. Without any help from a dedicated technician, any kind of construction engineer is able to work on his system and to fulfill his tasks. Everyone can start, use and shut down the system without specific process. This room is meant for different types of applications, from the technical design to simple communication events. It is free to access and replicas are built in other worldwide offices (Cuba, England and France). The formation is also taken into account as this room is open to students, university and start-ups to experiment with the works of construction. It aims to find a solution for BIM process design using virtual reality technology. In terms of cost, this room and the devices used in it are affordable, to ensure that it stays close to the ideas developed by [9].

One of the contributions of our approach is the identification of the user profiles taking part in the room usage. The Arcas room addresses the different problematic of each user profile. During communication events, with general public or prospects, the room must allow to present lead projects. The objective is to show the advantage of BIM and virtual reality and to demonstrate the expertise to a wide audience. For a client presentation, the focus is on one project and its results. It is thus necessary to show the most relevant and attractive parts for its future owner. For example, it is important to emphasize the urban integration by displaying the neighborhood, it is also essential to attain a high image quality. At least, in the BIM context, the room is a tool for designing and inspecting the virtual mock-up for the construction engineers. It should be noted that there are several different profiles for engineers depending on their department: architects, methods, structure…

This section describes the different systems included in the Arcas room. The possible application and use cases of the room are then explained, before a summarizing its integration in the workflow of construction engineers.

A. *An immersive room*

Immersive room systems are often based on a mono-user system [10]. However, collaborative works take a major act in architecture as described in[11]. It is important to propose different types of systems for the construction. Arcas room is the combination of several systems with several types of displays. These systems are placed around the center of the room as shown in Figure 2. Each system shows specific use.

Each system is linked to a computer integrating common operating system known by every collaborator. Systems are switching on and off depending on a central reservation

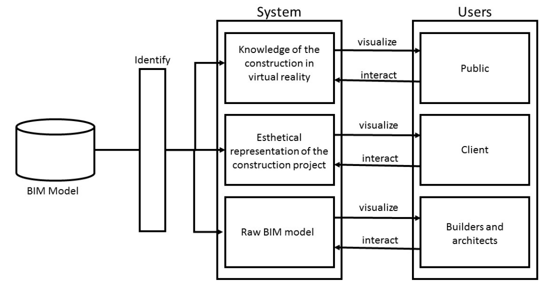

Figure 1. Interaction scheme for Arcas room: several use cases should be addressed by a user profile. From the demonstration of expertise for communication toward a wide audience, to project meeting for clients or technical collaboration with construction actors.

system. During the use of systems, no special command is required. The integration is seamless as the user uses his software environment, the same as his daily work. The interface relies on a keyboard-mouse device for every system.

The proposed systems are made for specific use and integrate innovative advances. Each of them is designed to solve a specific construction problem for BIM users. In the next section, we describe the systems and their technical description.

1) The cave: The cave is the largest system in the room, it is also the most complex one. The display screen is 6 m width per 2.5 m height, it can be set into any standard high-celling room. The screen integrates a 2.5m vertical radius curve, as shown in the picture in Figure 3. This curve captures the global field of view of the user and thus help for the immersion. The display start at 30 cm from the floor and end at 1,9 m. The aim is to set the middle of the screen at eye level for an average person. A sound system is set up all around the screen for audio immersion.

The device should answer architect needs and should provide a high quality display. The cave implements two high-definition projectors of 12000 lumen each, each projector displaying a part of the screen. With this kind of set-up, a warping and blending system is required to obtain a clear image. Two cameras, linked to the computer, are constantly capturing the screen to correct the image from the projector. They warp and blend the projector image to adapt to the curvature. The result is a 3272x1200 resolution screen, with a high luminosity, keeping a sufficient contrast, even when the room is lit. The system is stereoscopic and the refresh rate of the displayed pictures is 120 Hz.

As stated previously, the integration in the work environment is seamless as the system is switched off from the network, the stereoscopy and the warping is automatic. The mouse-keyboard interface and the presence of USB and internet connection duplicate the work environment for engineers. The users could work on a BIM model and also

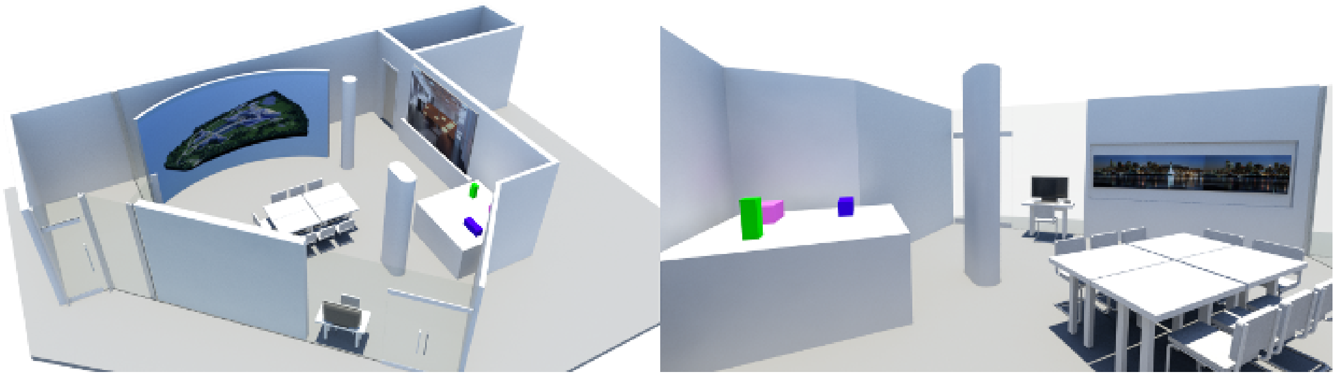

Figure 2. Arrangement of the Arcas room: several virtual reality systems around a mobile meeting table.

Figure 3. Pictures of the systems from the Arcas room. Top-left: the 3 TV system for additional displays. Top-right: the wall of screens. Bottom: cave system.

launch a document, video or sound, as every support is adapted to the screen size. As it is made for several users, no head-tracking device is installed. Users are immersed in a scale-one, i.e. objects are displayed at their real scales. The available applications propose the visualisation of an architectural project, a modernisation, a construction field or a simple 3D model. The users can then navigate into the model, select elements and get their associated information, and interact with the model, e.g. opening doors or changing the furniture. The professional software suites for the designers are also at hands. In this way, BIM users can create and modify any BIM model, they are able to perceive the building with the point of view of a worker or a simple visitor. The system is connected to a server to save the work directly on the original model, i.e. in the cloud.

2) Wall of screens: The wall of screens is composed by 4 high-definition screens with small bezels (thin borders around the screen). The TVs are assembled in square as shown in Figure 3. The device is managed by the computer as a simple, wide, screen.

In construction, a common practice for the engineers is to print every plan in the A0 format. The standard screen resolution is not comfortable enough to read plans. The wall of screen aims to find a way to display construction plans on a good dimension, keeping a resolution close to the one of the printed ones. This system proposes an ultra high definition (3840x2160) on a 110 inches (280 cm) diagonal. In this way, engineers can display construction plans which show all the project floors and which allows to discern the small measure written on. More over, a Wi-Fi connection is installed to display the screen of the user personal computer.

This resolution is also interesting to present ultra high definition images of the project. The image sharpness is important for interior designers who work on the atmosphere of a room and thus need very high quality display.

3) Additional set-up: Construction engineers often have other important documents to display during a construction meeting, like the planning or the building permits. The Arcas room allows to access to other TV for additional displays. The room contains 3 TVs aligned horizontally with a total resolution of 5760x1080 pixels. A picture of the set-up is shown in Figure 3. As the wall of screen, the additional TVs have a Wi-Fi mirror display function. Some communication applications are created for the device but they have to respect the 16x3/9 ratio.

The Arcas room also integrates augmented reality applications to visualize project models. As a branch of the virtual reality, the augmented reality aims to display virtual elements in a real scene. In the construction case, we propose to add the 3D model of a building on a 2D printed plan as shown in Figure 4. This new kind of tool proposes a new concept to visualize and communicate about an architectural project.

The third kind of systems is the head mount displays. Head mount systems the only fully immersive devices and the only mono-user. With the head mount displays, the user

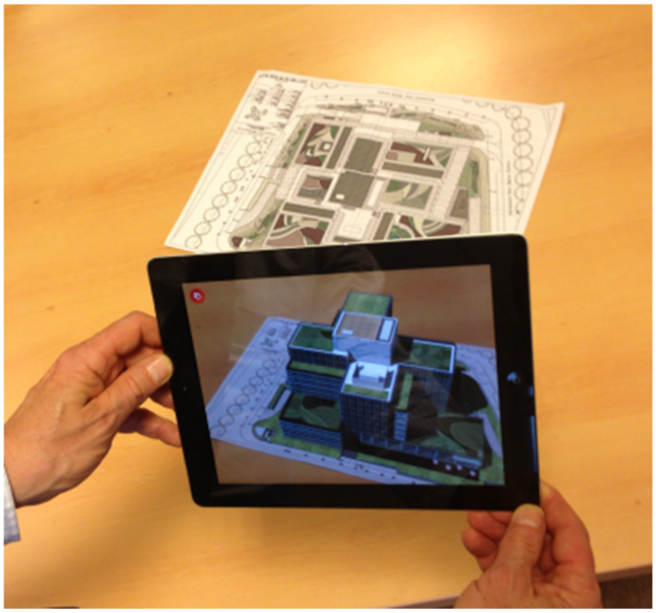

Figure 4. Augmented applications for the construction. The tablet captures the printed plan and superpose the 3D model of the corresponding project on it.

can feel the space and achieve a better experience in the project. The precision of these devices are not sufficient for inspecting a design properly, but they are useful to understand spaces for a person who is not used to reading a plan or a mock-up.

The last technology proposed in the room is 3D print. This is not virtual reality technology, but it is a tool which explains and help to visualize a project. 3D printed mock-up is still appreciated understanding a project where the geometry or the construction method is complicated. BIM models are printed in plastic and inspected by the construction actors. The printed object is a way to evaluate the aesthetic quality of the project or its feasibility.

B. Use case

These systems display different capabilities and the objective is to combine them in order to offer a complete working environment for BIM engineers. This room is also open for all kinds of building actors, coming from different departments. Communication and marketing can propose virtual reality applications for prospective or commercial purposes. In that case, the application requires a quality of images similar to the one needed by construction experts (as shown in Figure 3).

This room is also dedicated to raising awareness of security problems on the building sites. The builder is placed in a virtual site and is presented with the security processes during the construction. The simulation could even allow to reproduce the situation where a fellow builder or an object falls near the user. The immersive effect reinforces the importance of safety measures on-site, it is thus efficient to train people and to teach how to avoid risk-inducing behavior.

The Arcas room is now fully integrated in the workflow of the building design. The room allows to mediate the construction expertise, through the presentation of projects and the training of company's employees. The most innovative aspect relies in the integration of an immersive environment at the service of the BIM process. The Arcas room is the first virtual reality room dedicated to operating on building models and mock-up, using real case and operational projects.

IV. Experiments

We propose to evaluate the level of occupancy of the Arcas room regarding the profile of the users. The Arcas room is located in the center of the head office of Bouygues Construction. The room is free to use for employees of the company. This study measures the integration of the methodology proposed in this paper in a professional construction environment. Several profiles of users are defined. These profiles identify which type of using is the most needed, or at least the most present in the virtual reality room.

A. Methodology

For the logistic, a planning is systematically updated. It indexes and records the information regarding the reservation. From all the reservations, we identified four types of usage linked to the profiles defined in Section III.

- **Presentation to future users** which advertise and demonstrate to collaborators the virtual reality technology and the way it can improve their productivity. This aspect is mostly recorded to estimate this availability of the room.
- **Commercial & prospective** use. The project presentation for clients or the communication around the last innovation in the construction industry.
- **Technical** use, construction reviews, exchanges between project's engineers or architects, the creation or inspection of the project's model. Unlike the commercial and prospective, the technical use means a more advanced approach of the model and needs a minimum expertize.
- **Training** of the companions or workers to the last generation of construction methods or safety rules on a construction site.

The period of a reservation can range from one hour to half of the day. On average, a presentation to future users takes two hours. For the other type of use, the average is 4 hours. Then, we consider 2 days of maintenance per month, inspecting and improving the systems and fixing any kind of breakdown. The aim is to count every reservation without regarding its duration. We counted every reservation from the inauguration of the Arcas room the November 3rd 2014 to the May 31st 2016, i.e. 17 full months.

B. Results

Figure 5 draws the curves of occupancy of the room for each type of use during several months. At first sight, the occupancy plunged during the summer 2015, explained by the vacation and 17 days off where the room had been technically improved. The global occupancy of the room inched up on all the period to reach its maximum in May 2016. The 24 occupancies in one month describe the saturation of the room's availability. The presentations to future users show 3 pics. These pics represent the inauguration in November 2014, the communication campaign about the virtual reality in April 2015 and the inauguration after the system improvement in September 2015.

Concerning the 3 types of uses, the commercial and prospective presentation represents the earliest increase and reached a nominal value. The technical use shows a slower raise but is in 2016 the first use of the Arcas room. This curve describes the implementation of the virtual methodology in the company. At least, the training of workers represents the third type of use. With the arrival of the last generation of head mount display, and the improvement of the immersion technologies, this type of use shows the best perspective of evolution in construction virtual rooms.

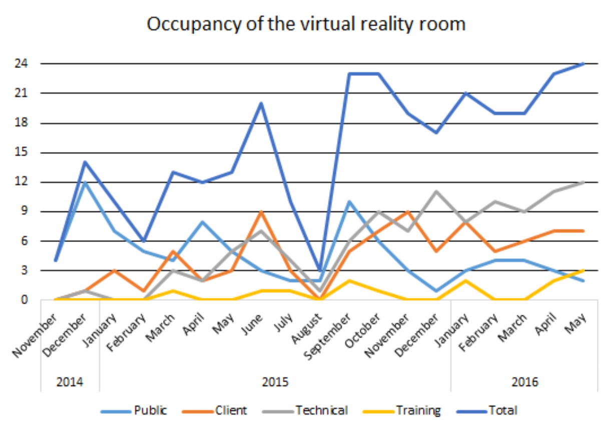

Figure 5. Occupancy of the Arcas Room. The four types of uses: presentation to future users, commercial and prospective, technical and training. The blue curve indicates the sum of all occupancy.

V. Conclusion

This studies shows the integration of the proposed system in a real applicative workflow. The virtual reality room is accompagnying the construction actors depending of different applications. Even if the commercial side, i.e. to present virtual and interactive architectural projects, is an important aspect, the usage of the room by construction engineers is a very good indicator of the adoption of the virtual reality in the BIM process.

The increased usage for training purpose, deeply relying on virtual reality, is calling for a methodological change in the teaching methods. For example, this room will be used for the training of workers on safety measures for specific construction site. The behavior of the workers could then be analysed to be later integrated in a new ”teaching” profile in the system.

Acknowledgment

This works was made with the collaboration of Bouygues Construction. The research has been financed in partnership with the ANRT (Association Nationale de Recherche et Technologie).

References

[1] B. Construction, Ed., *Construire avant de construire*, 2014.

[2] D. Chorafas and H. Steinmann, *Virtual reality: Practical applications in business and industry*. Prentice-Hall, Inc., 1995.

[3] J. Whyte, “Industrial applications of virtual reality in architecture and construction,” 2003.

[4] ——, “Innovation and users: virtual reality in the construction sector,” *Construction Management and Economics*, vol. 21, no. 6, pp. 565–572, 2003.

[5] P. MacLeamy, “Bim, bam, boom! how to build greener, high+ performance buildings,” *Urban Land Green magazine*, 2010.

[6] L. Khemlani, “Autodesk navisworks 2009,” *AECbytes Product Review*, 2008.

[7] G. Burdea and P. Coiffet, “Virtual reality technology,” *Presence: Teleoperators and virtual environments*, vol. 12, no. 6, pp. 663–664, 2003.

[8] A. Genty, “Projet callisto sari,” 2012.

[9] S. Kuntz and J. Cíger, “Low-cost and home-made immersive systems,” *The International Journal of Virtual Reality*, vol. 11, no. 3, pp. 9–17, 2012.

[10] M.-L. Ryan, *Narrative as virtual reality: Immersion and interactivity in literature and electronic media*. Johns Hopkins University Press, 2001.

[11] M. Baker, “Le rôle de la collaboration dans la construction d'explications,” *Actes des Deuxiemes journees” Explication” du PRC-GDR-IA du CNRS*, pp. 25–42, 1992.