

VIARMODES

Visualization and Interaction in Immersive Virtual Reality for the Architectural Design Process

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The complexity of today's architecture solutions brings the need to integrate, in the design process, digital tools for creation, visualization, representation and evaluation of design solutions. This paper proposes the adoption of a new Virtual Reality (VR) tool, referred to as VIARmodes, to support the architectural design process with an improved communication across different specialities, towards the facilitation of the project decision process. This tool allows a complete visualization of the design, specifically useful during the detailed design phase, including the architecture design and of other engineering specialities, progressively and interactively adapting the project visualization to the information needed for each discipline. With a set of 3 different visualization modes simulated in real scale within a Virtual Environment (VE), and adopting natural human-computer interaction by using speech, the system allows a team of architect and engineers, to visualize and interact with the proposed design during a collaborative design brief. We carried a usability evaluation study with 12 architects. The study showed that the tool was perceived to be effective and its use efficient during the design process, especially during the detailed design phase.

Keywords: AEC Architecture, Virtual Reality, CAVE, Visualization, HCI Human Computer Interaction

INTRODUCTION

Architectural design is a complex process where architects need to answer to a programme and to consider several requirements and constraints, ranging from environmental concerns including thermal

comfort, to safety conditions and social implications. In order to respond to those complex requirements, multidisciplinary teams are created and collaborative design sessions are usually performed during the design process.

More clear and explicit representations of a building are needed in order to clarify and inform the different stakeholders involved, allowing them to understand what is being designed during the different stages of a given architectural project.

The development of Computer Aided Design (CAD) tools, particularly 3D modelling and simulation software systems, for Architecture, Engineering and Construction (AEC), transformed the traditional design methods into more accurate and faster processes, allowing the architect to evaluate their designs (Carreiro and Pinto 2013). Today, these technologies are considered not just digital drawing tools, but also an integrated and dynamic part of the design process, from the early conceptual stage, addressing the detailed design, up to the production stage.

Throughout an architectural design process, the use of immersive VR, especially Cave Automatic Virtual Environment (CAVE) systems, allow for better spatial understanding of the architectural solutions, via the increased sense of presence and immersion that those systems enable. The immersion feeling is due to the real scale visualization of the designs and can be enhanced with an interaction via natural Human-Computer Interaction- HCI [7].

The goal of the research presented in this paper, was to specify, develop and evaluate a VR tool allowing rapid visualization of the design, especially to aid the communication between different specialities that intervene in the detailed stage of the architectural design process. Our tool serves the design brief scenario, where different stakeholders, such as architect, structural engineer, interior designer and other specialized engineers, need to meet, communicate and take joint decisions about the design. With our system, these stakeholders progressively and interactively adapt the visualization modes, to the information needed about the design. We have also created an innovative user interaction experience within the VE, by favouring natural human-computer interaction modalities, such as speech.

According to the above-mentioned goals, the

following methodology was established: definition of the architectural design process phases, by detailing the tools, graphic elements and data exchange standards used in each one; review of the existing state-of-the-art on the use of VR in Architecture; definition of the usage scenarios with the relevant stakeholders, and extraction of requirements for the proposed VR tool development; creation of a VR tool that meets the requirements and therefore can be used during the architectural design process, extending an in-house developed VR framework, applicable for all kinds of VR settings, from non-immersive to fully immersive (Soares 2010); usability evaluation of the developed VR application.

The VR setup used for this work was the Pocket-CAVE VR Lab, located at ISTAR-IUL (Information Sciences, Technologies and Architecture Research Center), at ISCTE-IUL in Lisbon. For the development environment, we've adopted the in-house CaveHollowspace VR C++ development environment (from now on CaveH) (Soares 2010). This environment allows developers to create specialized VR applications that enable users to experience the VE.

This paper is organised as follows. In RELATED WORK, we provide an overview specially of academic work in VR systems for AEC. In CAPTURING REQUIREMENTS OF A VR APPLICATION FOR AEC, we detail the methodology to capture the VIARmodes system requirements. VIARmodes APPLICATION details the main features of the system and USABILITY EVALUATION, describes the usability evaluation of the developed VR tool and discuss the obtained results. In the last section, we extract some conclusions and provide lines for future work.

RELATED WORK

The main purpose of VR is the realistic interactive visualization of an arbitrary virtual scene, supporting the 6 main characteristics theorized by Michael Heim in 1993: simulation of visual and other sensory information (such as 3D sound, smell, force feedback, tactile), frame update at interactive rates (> 24Hz), artificiality of the environment, sense of immersion, il-

Figure 1
Using CAVE BIM to
show an
architectural
design. [6]

Figure 2
Representation of a
3D virtual model,
AixCave. (Kuhlen
and Bischof 2010)

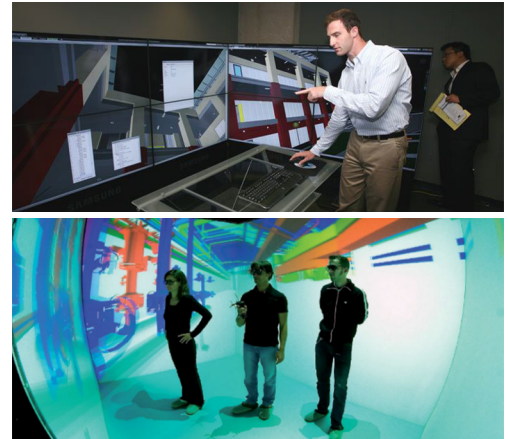
lusion of presence in the environment and network communication (Heim 1993). The virtual scene is obtained by modelling in 3D a certain environment, whether it is real (existing), proposed (will be done in the future) or just something conceptual/real (Monteiro 2011). Immersive VR systems, particularly the CAVE, are nowadays used in several areas from science to art, in mission critical activities, natural resources exploration, product design, medicine, cultural heritage, both in industry and in an academic context [7] (Mazuryk and Gervautz 1996).

In AEC, immersive VR emerges essentially as a tool for evaluation, discussion and presentation of the architectural design, usually during the stages (e.g. detailed design) where interaction and collaboration with other specialties, such as structural engineering, mechanic or electricity, is a requirement. Combining VR with Building Information Modelling (BIM) allows designers from different disciplines to focus their building systems enhancing design outcomes to avoid design conflicts (Kang et al. 2012) [6].

At A&M Texas University, the use of BIM Computer-Aided VE (CAVE BIM) system allows, both students and researchers, to analyse their designs considering their building systems (figure 1). A set of 12 monitors arranged in three walls with a U-shape, allow the visualization of the VE although without stereoscopic visualization, Using Autodesk NavisWorks, it is possible to interact, particularly by collisions and by doing modifications in the space, with a VE that shows multidisciplinary designs (Kang et al. 2012) [6].

The AixCave, at the VR research centre of the RWTH Aachen University, is a system with 5 projection plans with a 3D realistic representation, in a parallelepiped square with 5.25m wide by 3.30m tall large. The software - VR for Scientific Technical Applications (VISTA) - guarantees the development of applications for the majority of input and output VR devices, thus allowing an interactive exploration in a full immersive VE. A partnership between this research center and Formitas GmbH makes use of this technology (figure 2) in architectural designs in the past few

years, organizing meetings to discuss projects with architects, civil engineers and clients [4] (Kuhlen and Bischof 2010).



In the context of this work, the underlying technology is based on the CaveH system that was developed by ISCTE-IUL in Portugal. The first application of this technology was done in Centro de Ciência Viva at Lousal, Portugal. The physical structure of this CAVE, is of a U-topology and is composed by 6 projection planes, where 4 are retro-projected, with the size of 5.6 m x 2.7 m x 3.4 m, for groups up to 14 users (figure 3). The structure has a wide field of view (more than 180°) where 12 projectors (1400 x 1050 pixel) generate a 8.3M Pixel stereo pair at 60 Hz (with INFITEC Stereoscopy). The system includes a sound system, consisting of 6 speakers and 1 subwoofer, allowing both 7:1 surround sound and 3D sound auralization. The in-house developed software, CaveH, runs on Windows and comprises a serious game authoring environment and a run-time sub-system, including definition of 3D scenarios in different game levels, hierarchical character animation, 3D sound auralization of the scenario, free or pre-defined virtual camera paths and other features. A run-time system, developed in C++, and OpenSceneGraph (www.openscenegraph.org): ensures precise synchronization and 3D data consis-

tency among a set of computers on a LAN; enforces latency and bandwidth control (sustained 60 Hz); produces complex realistic real-time images, with Phong lighting and Phong shading; and allows texture mapping, rigid body dynamic simulation, collision detection, and spatialized 3D audio (Bastos and Dias 2008). Recently, our research team has developed a simpler portable version of this setup, fully compatible in what VR system software and applications are concerned, referred to as PocketCave, which is a one screen-only system, with Full HD resolution (1920 x 1080 pixel) in stereo, whose imaging is driven by a Depth-Q stereo projector, including a 7:1 surround sound system.

CAPTURING REQUIREMENTS OF A VR APPLICATION FOR AEC

Aiming at defining the requirements of a VR system targeting the detailed design stage of the building design process in AEC, we started by analysing the current practices in the industry, focusing on the adoption of 3D virtual modelling by designers, on the use of specific CAD systems and on the data exchange standards used.

With our study we aimed also at evaluating the benefit of different visualization modes adopted by the stakeholders throughout the design process. We prepared a questionnaire in an online platform (Qualtrics), which was distributed by email and social media, to be answered individually by architects (we did not include other stakeholders in this early study). 54 valid answers were obtained from a sample of professional architects with an average of 30 years, and 13 years of experience in the design process. The questionnaire was structured in 11 questions focused on: the effective use of 3D modelling tools during the architecture design process phases (adopting the Portuguese regulation for such standard architectural design process phases); the tools and sketches needed to represent architecture design in the different phases of design; and the necessary steps taken during the development of a design activity. The results of the users study are depicted in

Table 1 and Table 2.



Architectural design process phases	To evaluate volumetric characteristics of space	To evaluate constructive options	To be used as a medium for communication between various specialties	For project briefings
1 – Conceptual Programme	22	1	4	14
2 – Preliminary Design	43	11	24	38
3 – Basic Design	26	25	31	41
4 – Detailed Design	9	25	26	17
5 – Technical Assistance for Facility Management	6	10	13	14
in none	1	9	7	1
NP Answers	107	81	105	125

Visualization and modelling tools		Representation types					
		Abstract representation with or without shading and colours of materials	Shaded surfaces with colours of materials	Distinguishes the various specialties of the project (Layers)	Transparency	Shadows	Texture maps
3D model and visualization tools	Autocad 3D	X	X	X	X	X	X
	Revit	X	X	X	X	X	X
	3DSutdio Max	X	X	X		X	X
	Rhinoce ros	X	X	X	X	X	X
Representation of 3D models for architectural tasks (Questionnaire of Requirements)		X	X	X			X

The majority of architects (78%), claimed to use 3D modelling and visualization tools in the design process and 74% considered the development of 3D models during the project as useful. According to Table 1, architects believe that, during the Conceptual Program (41%) and Preliminary Design (80%), 3D modelling tools are useful to evaluate the architectural design, even if only simulating volumes. In the Basic Design, subjects considered such tools to be more relevant to the presentation of the project to other stakeholders (76%). During the Detailed Design, architects ranked highly (94%), the advantages

Figure 3
Navigation in the “Virtual Mine” serious game, in CAVE-Hollowspace. (Soares et al. 2010)

Table 1
Relevance of using 3D modelling tools in the different phases of the architectural design process (Portuguese Standard). (Units - number of times an option was chosen)

Table 2
Representation types used by 3D modelling and visualization tools in the different phases of architectural design process. [1] [2]

Figure 4
Villa Savoye
representation in
the Shaded Mode

of using 3D modelling tools to aid the communication between different specialities in the project design and to improve the assessment of construction options.

Our study revealed also that, during the first stages of conceptual design, architects express their ideas by creating simple volumes, with which they start to develop the preliminary ideas. After the definition of the overall design proposal, architects aim at clarifying the initial ideas and defining the architectural design, by developing 3D draft models. Detailed design follows and other disciplines come into play with their own design proposals that need to be compatible with each other and with the design proposal of the architect.

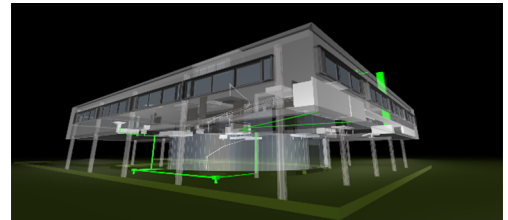
The outcomes of the questionnaire and the related work analysis, allowed us to come up with a set of requirements (table 2 - Representation of 3D models for architectural tasks) to guide the development of the VIARmodes system, focused on the improvement of the communication of various disciplines that intervene in the design of a building, especially targeting the detailed design process. The developed system is detailed in the next section.

VIARMODES APPLICATION

The VIARmodes VR application supports three visualization modes specially designed to serve different phases of the architectural design process, in the framework of the overall AEC design process, namely, Shaded Surfaces mode, Layered (Specialities) mode and Textured mode. All modes make use of features already built in the CaveH system, such as: collision detection; import of external objects, composed by materials and textures; manual and automatic navigation (6 degrees of freedom - DOF - on translation and 2 DOF on rotation; avatar parameterization; and Phong lighting, Phong shading and Texture Mapping. Each mode have a specific set of features which meet the requirements identified by the survey's results.



Particularly, the Shaded Surfaces mode (figure 4) is a type of visualization that aims to be simple and allows a clear visualization of the geometry and shape of the scene without the "intrusive" presence of textures. The lack of textured objects, allows the architect to design the 3D model in a faster way by ignoring the need of realistic aspects of the design. This mode renders objects with standard object sorting approach for visualization, without considering object's transparency. With geometry and materials defined in an early stage, the architect can already experience the space by observing shaded objects.



The Layered mode (figure 5) was the feature which required more software development, given its complexity. The goal of this mode is to allow the user to discretize one or several design specialities, so that, for example, in a detailed design brief (including e.g. architect, structural and mechanical engineers), all the experts can play an active part in the discussion, by manipulating geometries of the correct corresponding construction elements (layers). This mode simulates a conceptual environment where each layer, that models the contribution to the design of a given specialist, has an associated standard "false" colour defined by the user. This mode allows transparency with an object order dependent algo-

Figure 5
Villa Savoye
representation in
the Layered Mode

rithm and the user is able to iterate through three different layer states: invisible, transparent and drawn with objects material properties.



The Textured visualization mode (figure 6) achieves a more realistic visualization in a later stage of the architectural design process, where the architect can add textured models for design briefs with the client and other stakeholders.

VIARmodes data processing pipeline

VIARmodes follows a specific scene modelling pipeline. Blender, an open-source 3D modelling tool, with our CaveH plug-in installed, is where authoring of the 3D VE takes place, including the geometry of the scene, its lighting, sound sources, virtual camera control, etc. Each 3D model has to be first imported in Blender (v2.60, at the time of writing of this paper), for scene composition. After authoring, the 3D scene and all its models, can be exported to ".osg", using our CaveH plug-in. The .osg format is directly consumed by the VIARmodes run-time sub-system.

Autodesk Revit 2014 was initially used to develop the 3D models, due to being widespread in the architecture practice and given the benefits of its use in the construction industry. Other 3D modelling systems, such as Rhinoceros3D and 3D Studio Max software are also compatible with our data pipeline (Moural et al. 2013). The texture mapping work for this study, was carried out in Blender.

The NP EN ISO 13567 CAD layer naming standard was adopted, in order to classify each scene object according to the construction element and speciality it represents. In our test cases, the building was modelled taking into account 6 different layers. Each

layer corresponds to an AEC speciality and has a different "false" colour, which can be highlighted, when simulating in Layered mode: Structure (red), Walls (yellow), Pavements and Ceilings (Orange), Openings (Blue), Infrastructures (Green), Equipment and Furniture (Grey). Assigning materials and objects to layers is performed either during the object's modelling third party tool or with Blender. VIARmodes allows also the definition of an arbitrary number of layers and assigned names, as well as of the colours associated to each layer, supporting complex designs.

Natural human-computer interaction using speech

To iterate through each visualization mode and enabling/disabling each layer, we use speech interaction, by adopting the Microsoft Public Speech Platform. Our technique requires the definition of a context free grammar of commands, for a typical command and control user experience. The speech commands are uttered in European Portuguese (other languages such as English are supported too) and each operation can be triggered by one or more voice commands, as it is shown below:

[Operation]: Change display modes:

- "Muda para o modo sombreado" "Muda para o modo de camadas" (change to shaded visualization mode) (change to layered visualization mode)

[Operation]: Switch features:

- "Liga estruturas" "Desliga paredes" "Põe as paredes transparentes" (turn on structures) (turn off walls) (set transparency to the walls)

The grammar used for speech interaction can be edited according to the commands the user wants to trigger upon recognition of a certain pronounced phrase.

Order dependent transparency

To ensure the correct object rendering taking into account each object translucency, especially in the Lay-

Figure 6
Villa Savoye
representation in
the Textured Mode

ered mode, we forced the scene graph objects with such propriety, to be rendered in the proper order so that the transparency effect is painted correctly. Each object's render order is computed based on its position and orientation relative to the camera's pose, which is calculated based on each object's bounding box. In our test scenes, several objects have a bounding box that might intersect other objects bounding boxes, which results in more complex ordering of the objects to render. Due to OSG system limitations, the Order Independent Transparency (OIT) proved not to be a viable technique for this problem. OSG has a quad buffered technique that implements stereoscopic rendering, which takes a 3D scene as input and generates two pairs of images (a double-buffer) for each eye, thus creating the stereoscopic visualization effect. OIT, on the contrary, uses multiple-pass rendering [3], where the final output to the quad buffer is a single textured quad (not the original 3D scene), that does not take the eye separation into account.

To solve this issue we developed an object ordering algorithm, which uses a volumetric organization of the scene graph objects in an octree, based on the distance from the camera to the nearest object, that in turn is based in which octant (of the octree) the camera is positioned. First, we store the distance between opposing vertices of the scene's global `osg::BoundingBox` and divide it into "levels" of depth across the scene (thereafter called "renderbins"), from the camera viewpoint perspective. Then the scene is traversed in each frame, evaluating the distance between the camera and the nearest vertex of each object bounding box. For each of those distances, we assign a corresponding renderbin, therefore ordering the scene by objects' bounding box. This method improved somewhat the behaviour of the run-time application when faced with multiple transparent objects.

Modes and layers handling and HCI

The run-time app includes a Phong shader that provides some basic features regarding scene lighting, taking into account the material proprieties of the

objects. To interact with the application, the user has two types of HCI modalities: a standard keyboard and mouse modality and speech.

Regarding the more traditional HCI approach, one predefined key was assigned to cycle between the three modes of visualization and another set of keys were associated to each layer, allowing also the user to cycle between the already mentioned states per layer. This interface is needed to ensure a basic way of interacting with the application although it has some drawbacks, such as the challenge to associate a key to its respective layer.

The speech input HCI modality solves this problem, since there's an unlimited context free grammar that can be used as input to communicate with the application in a command and control scenario. The speech recognition module is coded in C-sharp and communicates with the main application by a TCP/IP socket. The grammar is defined by the user in a XML configuration file that is parsed in load time to identify the `osg::Group`'s that needs to be created as a response to the recognized speech command.

This is an important feature, since the audience for this application (architects, engineers, technicians, clients, real-estate promoters), may not be used to deal with VR technology, and therefore a more natural way of interaction may enable a more efficient and effective use of the system.

USABILITY EVALUATION

In a later stage of the app development, a usability evaluation study was conducted in order to: investigate the relevance of this technology and its integration throughout the architectural design process; and identify potential gaps, app breakdowns and improvements to be implemented in future work.

The usability evaluation study was conducted in a controlled environment, with the hardware and software of the PocketCave system, described in section 2nd. The evaluation included 12 participants, all architects with an average of 42 years, and with experience in the design process ranging from 1 to above 30 years (average of 20 years). The user experiment,

individually performed, was divided in three parts:

1. Presentation of the study goals by the observer, and briefing regarding the concept of the application, followed by a preliminary survey in order to collect data on the participant;

2. Demonstration of the VIARmodes application by the observer.

3. Hands-on usability evaluation study by each participant of the technology and its features in immersive VR, with a fixed time duration. For this evaluation, we've set up a scenario of a simulated project physical meeting held in the same location, between the experimental subject (an architect) and the observer (a member of our team who is a trainee architect). The architect was acting as an "architect persona", whereas the observer took the role of other discipline of the design (e.g. "structural engineer" persona). The goal was that the architect could explore the building in an interactive way while conducting a meeting with a stakeholder with other expertise, by just carrying a conversation. The virtual experience was controlled by the observer, who was the only one that interacted with VIARmodes via speech, following the requests of the architect when manipulating AEC objects, posing his own commands and controls, or via keyboard and mouse to navigate in the VE (per the architect request, figure 7). The observations given by the participants were also registered;

4. At the end of the session, the participants answered a subjective survey on the technology demonstrated and used, aimed to assess the relevance of its adoption throughout the architectural design process.

RESULTS AND DISCUSSION

By analysing the first questionnaire, we concluded that 83% of those surveyed, ranked their relationship with digital technologies, between reasonable and very good, and 75% claimed to use digital 3D models throughout the design process.

The outcomes from the second questionnaire showed: the effectiveness of communication and

representation of the VIARmodes application in VR, for architectural design (table 3); the very positive opinion of the participants regarding the integration of this technology in the design process (table 4); and also shows in which phases of the architectural design process (table 5), and in which tasks (table 6), each visualization mode is more useful. In Tables 3 and 4, the architects had to score 8 statements, on a scale from 1 to 5, equivalent to "strongly disagree" and "strongly agree", respectively.

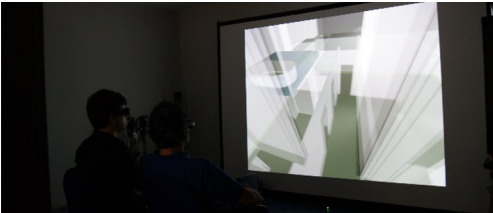


Figure 7
Usability evaluation session with the PocketCave @ ISCTE-IUL. (September, 2014)

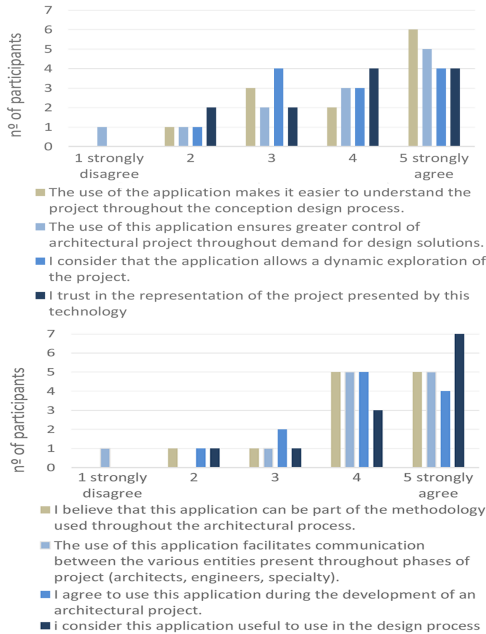


Table 3
Analysis of VIARmodes system, on the representation and communication of the architectural design.

Table 4
Receptivity and conviction on the integration of VIARmodes application into the methodology of the architectural design process.

Regarding the representation of the 3D model (table 3), considering the answers obtained between

Table 5
Relevance of the visualisation modes in the different phases of the architectural design process (Portuguese Standard). (Units - number of times an option was chosen)

scale 4 and 5, 67% of the architects revealed to have confidence in the representation allowed by our approach, and consider that the VIARmodes application helps in understanding the project itself throughout its conceptual design phase. We can consider that the use of this technology is already robust enough to bring benefits by enabling more effective communication and better comprehension of the design options of an architectural project.

Table 4 shows that 84% of participants (with scales between 4 and 5) consider VIARmodes as a valuable and helpful tool to integrate in the design process, enabling the improvement of the communication between different specialities. Most architects (75%) claim they would be willing to use this technology in the development of their own architectural designs.

The data in Table 5 shows that VIARmodes is considered a versatile tool for the majority of the design phases. Participants revealed the importance of each display mode in the different design stages with similar opinions. Still, the Shaded Surfaces mode, obtained unanimously a greater relevance in the Conceptual Program and Preliminary Design. The Layered mode stands out in the following stages of the project: Basic Design, Detailed Design and Technical Assistance for Facility Management, while the Realistic Mode gains relevance in the Preliminary Design, Basic Design and Detailed Design.

According to Table 6, we may conclude that, in one hand, the Shaded Surfaces mode was chosen as a relevant feature for the communication between the architect and the specialities team. On the other hand, the Layered Mode stands out to be relevant on the collaboration, communication and sharing among different specialities of the project, and also in the technical assistance for facility management. The Realistic Model is considered relevant on the communication and presentation of the project, mainly during briefings between the architecture team and the client.

Table 6
Utility of visualization modes for different tasks in the architecture process. (Units - number of times an option was chosen)

VIARmodes use in the architectural design process phases	Shaded Surfaces	Layered Mode	Realistic Model
1 – Conceptual Programme	9	1	4
2 – Preliminary Design	12	6	6
3 – Basic Design	9	10	9
4 – Detailed Design	3	9	6
5 – Technical Assistance for Facility Management	1	9	4
In none	0	0	1
Nº Answers	34	35	30

As a final appreciation, users (68%) found VIARmodes very useful to a dynamic exploration of the architectural design in the full design process. Some of the observations and suggestions, also revealed in this section, are valuable to guide further development work.

VIARmodes use for tasks of architecture design	Shaded Surfaces	Layered Mode	Realistic Model
Conception of architect	10	6	6
Work within the architecture team	8	10	8
Work meetings between the various specialities	3	11	5
Meetings with clients	6	2	11
Work for facility management	0	8	5
In none	0	0	1
Nº Answers	27	37	36

CONCLUSION AND FUTURE WORK

This paper presents a new tool for visualization and interaction, in immersive virtual reality, of architectural designs, referred to as VIARmodes, and highlights some aspects on how it contributes to the improvement of architectural design process, throughout its different phases. Usability evaluation studies carried with 12 architects, revealed that the participants considered that the experience and the direct confrontation with the full-scale architectural objects in a semi-immersive setting, favours the dialogue and communication between the different stakeholders of the architecture design process, and guarantees significant improvements during such process. They also valued the natural user interaction through speech, highlighting the advantages of being able to separate the project into pieces and to combine the presentation of specific layers, each one associated to a project discipline. We can conclude that this feature helps to take more informed

and focused project decisions, regarding architectural choices in the design phases and most likely during its construction too. Therefore, we believe that the integration of this technology in the design process, provides improved understanding and control on the overall multi-speciality architectural design, since the representation of the project in VR is progressively adjusted according to a specific process phase and task. Despite the positive outcomes, a few improvements are considered important. As a future line of work, the control of lighting, shading and shadowing has to be upgraded in order to enable a full presence of light in the spaces. More realistic texture mapping techniques could be adopted, in order to improve the satisfaction towards using this technology making the models more realistic. We also intend to make it possible to depict on the screen, additional graphical elements, such as sections and plans emphasizing and facilitating the orientation in the 3D model. Another future goal is to implement a user experience allowing direct editing of the VE objects. There is also a clear intention to improve VIARmodes to support the visualization and interaction with complete BIM models (beyond the geometric and topological component), in a VR setting, including 4D (3D + time) simulation to drive construction planning, cost simulation and Facility Management support. Another attractive aspect is the possibility of using this technology in other areas such as entertainment, with simulations of interactive environments, for product design and evaluation in other industries, in archaeology and history to the exploitation and rehabilitation of historical sites, or even in medicine, with the creation of virtual sets, both for training surgeries or to treat phobias (VALE et al. 2009).

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