Multimodal interaction with BIM data in immersive virtual reality

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1. INTRODUCTION

The use of new computing technologies in architecture design has evolved the working methods and the way designers relate with the space they are designing. To express their ideas, designers use tools such as physical scale models of buildings in urban settings, sketches and rigorous drawings that are often difficult to understand by non-designers. Therefore, it is common that architect designers have some difficulties when discussing with different stakeholders about their projects. Improving the communication between architects and other experts in the full-life cycle of building design, including architecture, engineering, construction and maintenance stakeholders, is therefore mandatory and require the introduction of new tools. The adoption of BIM (Building Information Model) standards, models, processes and support tools in AEC – Architecture, Engineering and Construction, is bringing considerable benefits to the industry, by providing physical and functional information about the different elements of the design, in a structured, standard and interoperable way, during its different stages (conceptual design, detailed design, construction and maintenance), facilitating the collaboration among professionals of architecture and of different engineering specialties. The usage of BIM enables not only efficient design and documentation of all the building design parts, but also automatic identification of design errors or clashes amongst the design proposals of different specialties, that often arise during the design process. The use of BIM allows designers to have a quick access to more detailed and structured information about all components of the building model in 3D (Carvalho, 2012). In this paper, we combine the potential brought by BIM standards to AEC processes, with the recent trends and results taken from human-computer interaction (HCI). As a result, our system supports the visualization and interaction with 3D BIM models of buildings, at full scale in an immersive virtual reality (VR) environment, using natural and multimodal HCI, namely, combining gesture with speech. We´ve carried usability and user satisfaction evaluation with a panel of architects, engineers and architect students and our research shows that such an environment allows a deeper understanding of the work throughout the design process and improve the communication between AEC specialties, during design briefs. We have concluded also, that our technology offers great benefits during all the stages of design, from the initial phase of conceptual design until the detailed stages up to the construction work. The practical experimentation of our in-house developed system, was possible by taking advantage of the virtual reality facilities of ISCTE-IUL, namely, its PocketCAVE lab.

2. GOALS AND METHODOLOGY

Our research aims to enhance the use of BIM technology in immersive virtual reality, using natural and multimodal HCI, promoting a reflection of how this type of combined use may benefit the architecture professionals, in the building design process. Thus, the objectives of this practical work are:

- Capture user requirements and define the visualization characteristics of a BIM model that are useful during a meeting between different design experts of the AEC industry.
- Based on such requirements, develop and evaluate with a panel of users, a VR system that allows:
  - Visualization of a BIM model in 3D, to be use in a semi-immersive virtual reality environment (PocketCAVE);
  - Natural and multimodal human-computer interaction using gestures and speech;
  - Exploration of the BIM model and all its modeled building elements independently, allowing to obtain metadata about them;
  - Visualization and introduction of comments in the BIM model.

Our research followed the following methodology: 1) Define personas and usage scenarios regarding the exploration of BIM data to serve collaborative AEC design processes. 2) Derive user requirements and then specifications of system features, from such personas and scenarios; 3) Use available BIM models (in 3D) and create new ones to test, explore and evaluate the system. 4) Develop the VR system, referred to as VIARmodes4BIM, according to the plan; 5) Perform usability and satisfaction user studies to assess the validity of our approach.

3. VIARModes4BIM

3.1. PERSONAS, SCENARIOS AND USER REQUIREMENTS

In order to identify the essential characteristics our VR system, we defined 3 personas (an architect, an engineer and a builder) and identified two usage scenarios: 1) a meeting between architects, 2) a meeting between an architect, an engineer and a builder. In both scenarios, personas are implicated in tasks and discussions about the project and therefore need to navigate through the building and visualize specific elements as well as select and comment them. The advantage taken with our approach, of defining close to reality scenarios, is that problems and usability issues arise beforehand, and these can be captured, influencing the definition of requirements and system features. The final set of user requirements for the proposed VR system, were: user selects a BIM element of a given AEC specialty, performing a spatial deictic utterance (using words such as “this”, “that”, “these”, “those”), while pointing with his/her hand to spatial BIM element in the VR scene that the speaker is referring to ; users inserts a comment using speech (in an element that was previously selected); users asks to view all inserted comments, using speech; user asks to show one or more or all the AEC design specialties (show the BIM model in the desired specialty and subspecialty), using speech; produce a feedback report.

3.2. VR SYSTEM FEATURES

The VIARmodes4BIM system is an evolution of a previously developed VR system, VIARmodes (Coroado et al, 2015). The system already supported three display modes: a mode of layers where the model is divided by specialties, featuring a different false color for each one of them and three transparency levels: opaque (0%), transparent (10%) and turned off (100%); and a shaded mode, where the model is presented with a Phong shaded model. From the set of requirements presented in the previous section, new features were developed and integrated in order to take advantage of the BIM model. Thus, for VIARmodes4BIM we developed the following features (note: speech recognition in our system is supported for European Portuguese, using Microsoft technology):

- Read and load BIM models, following Industry Foundation Class standard (ISO 16739) COBie Model View Definition (Construction Operations Building Information Exchange). Currently we support only the gemoetric and topological parts of the standard.
- Perform multimodal interaction (speech command with a deictic utterance, synchronized with a gesture), to select elements of the BIM model. Speech commands rely on a predefined context-free grammar;
- Dictated speech to express comments added as metadata to select elements of the BIM model. Speech dictation uses a language model of European Portuguese, with 421K unique words that follows the orthographic agreement for the Portuguese, and was trained with more than 35 million phrases, taken form SMS, emails, facebook messenger and WhatsApp messaging data, old and recent newspaper data, Bing data and transcribed data from speech corpora.

Regarding devices that enabled the listed features, VR navigation is currently supported with keyboard and mouse, with which users are familiar. A close talk microphone (on a headset), is used for the pronunciation of voice commands as well and dictated speech. A Kinect 360 device SDK is used to capture and recognize pointing hand gestures. The free VR navigation and the possibility to interact within the immersive virtual environment, allows the user to have an experience close to the real situation. To emphasize this sense of reality, our VR system includes a collision feature, which prevents fixed elements, for example walls, to be overpassed. To implement the specialties selection feature, the layers of display mode of VIARmodes were used (Coroado et al, 2015). The system structures the BIM model by a configurable number of specialties, which, in our test cases are: Architecture, Structural Engineering, Mechanical Engineering, Infrastructure (Water and Sewage) and Furniture and Equipment. The Architecture specialty, has a configurable number of subspecialties. In our data models, we´ve used, Walls, Floors, Ceilings, Stairs and Openings. Each of these specialties and subspecialties, has its own false color, to be distinguished in the virtual environment. As mentioned, the developed system allows the selection of BIM elements. While navigating in VR, the user may want to select a specific element of the model, belonging to a given speciality, to include a comment. To that purpose, the user produces a deictic utterance, while pointing his/her hand to such element, and the selected element that is closest to the avatar is selected. The user might want to insert a comment, to a given BIM element that was previously selected, to remember later the changes he/her has to do in its design. The insertion of comments is done by free dictated speech, converted into text by the speech recognition feature of our system. A window is displayed on the screen (using an orthographic virtual camera in a heads-up display), allowing the user to visualize all the comments that were made to the elements during the session. All comments entered during the session are stored for later visualization in the virtual environment, or can be exported by the designers to third party AEC design systems (such as Autodesk Revit), in order to work on them.

3.3. BIM DATA PREPARATION

To prepare the BIM data to be consumed by our VR system, we need to carry out a series of steps from 3D modeling to the presentation in VIARModes4BIM. The BIM software used to author the 3D building models, is Autodesk Revit which is adopted by ISCTE-IUL Architecture curricula. For the process to be carried out effectively, certain rules were established for the 3D modeling of the project: scale units, intersection elements, division by AEC layers, intersection elements and transposition between different software (Alves, 2015).

3.4. USABILITY EVALUATION STUDY

We performed a usability and satisfaction evaluation study involving 15 adult participants from ISCTE-IUL. This study focused primarily on master's students of Architecture. The study took place in three phases: VIARModes4BIM demonstration performed by the authors, followed by free exploratory experience of the system by each participant with a fixed time, and in a final subsequent phase, each participant had to perform 3 prescribed tasks in random order. By analyzing the results, about 80% of the subjects claim to be easy to interact with the system using speech (unimodal approach), while 60% claimed to be easy to interact in a multimodal manner, using deictic utterances and gesture. 90% of participants reported that posting comments via dictation, visualizing and interacting with AEC specialties and with comments posted to elements, makes this VR system useful for both conceptual and detailed design phases.

4. DISCUSSION

Our developed VIARmodes4BIM system has a series of features that enable visualizing and interacting with BIM data in virtual reality environments. The visualization features and the natural multimodal interaction, allows users of different AEC specialties to preview and explore the building in full scale, and to experience an improved sense of presence and interactivity while carrying collaborative design briefs, which favors the comprehension of the multidisciplinary project and its volumetric space. Designers can meet with colleagues, other experts and stakeholders and use natural communication ways (by exercising speech and gesture), to visualize, select and comment building elements of a BIM model in VR. Particularly, the embedded natural and multimodal HCI, allows the interaction to be made by speech and gesture, which increases its usability and user satisfaction by making the interaction simpler and more natural.

5. FUTURE WORK

Regarding future work, we expect to implement the following new features, that arose both from the feedback of participants in our user study, as well from our analysis of the state-of-the-art: read the full IFC (ISO 16739) COBie Model View Definition, including geometry, topology, and business data; presentation and interaction with design incompatibilities/clashes from different specialties; export the full IFC file back to the BIM authoring system, allowing the user to open the BIM software visualize all the changes that were suggested during the collaborative design session with VIARmodes4BIM; support navigation in the virtual environment through multimodal HCI, using gestures and speech; allow more than one person simultaneously interacting through multimodal HCI; recognition of speech using the Kinect sensor.

6. REFERENCES

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