Ergonomics in Design, Vol. 47, 2022, 448–456
https://doi.org/10.54941/ahfe1001969

A Workflow for Multi-user VR Application Within the Physical Classrooms of Architecture and Urbanism Courses

Emerson Gomes[1,3], Francisco Rebelo[1,2], Naylor Vilas Boas[3], Paulo Noriega[1,2], and Elizângela Vilar[1,2]

[1]CIAUD, Research Centre for Architecture, Urbanism and Design, Lisbon School of Architecture, University of Lisboa, Portugal
[2]TI-LARSyS, Universidade de Lisboa, Rua Sá Nogueira, 1349-063, Portugal
[3]PROURB, Postgraduate Program in Urbanism of the Faculty of Architecture and Urbanism of the Federal University of Rio de Janeiro, Brazil

ABSTRACT

This article presents a workflow for virtual reality application with multiple users in face-to-face architecture classes. The problem posed is that the application of collaborative VR (with interaction through avatars) in physical classrooms is still little discussed. Thus, the work suggests that the immersive tool is integrated with the others already commonly used in the daily life of disciplines, such as photographs, videos, technical plans, among others, so that there is flexibility and ease to switch between common and immersive classes, without the need to leave the physical room. Methods include bibliographic review and preliminary experiences of authors with VR in the teaching of architecture. The results indicate a 5-step flow demonstrating how to apply VR in the college classroom.

Keywords: Virtual reality, Architectural teaching, Metaverse

INTRODUCTION

Following the line of metaverses, the use of VR in multi-user mode for teaching architecture has great potential, including in the context of classes in physical rooms of faculties. Among the main advantages is the possibility of offering students many guided tours in buildings of didactic relevance, something often desired by students and professors of many courses.

In the field of architecture and urbanism, reflections on the theories and examples of the past continue to play important didactic roles for graduation. Architectural spaces produced several centuries ago remain valuable to this day, and with theories often applicable in contemporary times. Subjects such as History of Architecture and Architectural Studio are common in the most diverse faculties, and can be considered anchors in architectural practice. (Hein and van Dooren, 2020). In this sense, the ways in which such knowledge is passed on has an impact on the result of professional training, hence the importance of using techniques and methods that contribute to keep students engaged (Ge, 2019). In this way, guided tours are a positive example in improving student enthusiasm and learning. (Ge, 2019; Hein and van Dooren, 2020). For example, Hein and van Dooren found, among other things, that contact with physical buildings outside of college results in inspiring experiences for students and is therefore of great value for teaching. In this same vein, during the first half of the last century, canonical authors such as Zevi and Corbusier already mentioned the relevance of being present on site to study a building, especially through a simple walk, that is, when the observer explores successive points of view, which arise at every step (Zevi, 1996).

Thus, it is based on the understanding that classes in the form of guided tours (outside of college) in architecture courses are of great importance for learning, especially when didactic content is eminently theoretical. Therefore, guided tours can be considered a way to bring students closer to reality, a practical mode for the teacher to present a real sample of what is being taught.

However, given the enormous geographic extension and the different historical periods, the realization of visits is often unfeasible or even impossible, as there are places that no longer exist or have been strongly modified over the course of history. In addition, in general, the time, distances and financial resources needed to make travel possible constitute barriers that limit students' access to places considered important to be visited in the context of a class. In addition, the post-pandemic scenario of Covid 19 and sustainability issues are obstacles to carrying out the visits. In this sense, the use of VR as a tool to improve the teaching of architectural history proves to be an interesting alternative, especially for the possibility of carrying out collective virtual visits, allowing the student to feel present in the place, on a real scale and in a situation of class, that is, participants dialogue and interact with their colleagues and teacher through avatars.

It so happens that the application of VR in the classroom is still not widely discussed, especially when considering collective use. Thus, what is proposed is a workflow for the implementation of multi-user virtual reality in architecture teaching, within physical classrooms, based on current immersive technologies and on the authors' experiences with the use of VR. The goal of this is to allow, during a conventional class, that the teacher has the freedom and flexibility to use traditional tools, and when he finds it convenient, can invite students to enter the virtual environment and visit the studied place, continuing the class through avatars, walking, and talking in the virtual environment, without this implying an abrupt break in the natural rhythm of the class.

Investigation Problem

Architecture has a long history to be told, from ancient to modern times, and by geographically covering several continents, it results in an extensive and potentially tiring content, with a great chance of transforming the transfer of information into something tedious. (Ge, 2019). In theoretical subjects such as Theory and History of Architecture, the teacher often uses photographs and filming, which, in addition to plans and other graphic means, allow a sample of the work under study to be passed on. This pedagogical practice is widely used, but it has gaps because the student's interpretation of space is often limited to the samples that were presented to him, and may fall into a fragmented reading or with the possibility of distortions. (Zevi, 1996). In this sense, some authors have been investigating VR as a way to mitigate such problems, and have found positive results, for example. (Ge, 2019; Gaafar, 2021; Ibrahim, Al-Rababah and Bani Baker, 2021).

In general, these investigations suggest the application of virtual reality in the teaching of architecture, but it is still not clear how this can be implemented in the day-to-day of the disciplines, especially if we consider face-to-face classes in faculties, that is, with a professor and students occupying a physical classroom.

OBJECTIVES

Considering the guided context, the general objective of the present investigation is to propose a workflow that allows the teacher, during a conventional class, to lead students on a virtual guided tour, allowing everyone to interact and communicate through avatars, without leaving of the college physical classroom. Therefore, the application of multi-user VR is proposed as a tool to be flexibly and harmoniously integrated with the others that are already used in the classroom.

METHODS

The methods chosen initially to involve an analysis of the existing literature, looking for the various examples of application of VR in the teaching of architecture, especially those that carried out guided tours as a pedagogical tool. Next, a flow is proposed based on pilot experiments carried out in the city of Belém, in Brazil, with students and professors of architecture, as well as in previous works developed by the authors in the laboratories Ergo Lab, University of Lisbon, in Portugal, and LAURD/PROURB, Federal University of Rio de Janeiro, in Brazil.

The authors' experience involves more than 10 years of work that associate VR with architecture, such as Vilar et al. (2013, 2014), Gomes et al (2018). Pilot studies have been applied more recently in physical classrooms. In them, the teacher promoted immersion as a way of improving conventional classes, keeping multiple students simultaneously immersed in the digital environment, thus carrying out a virtual guided tour.

CONCEPTS

Initially it is relevant to demarcate some important basic concepts to understand the following paragraphs. Below is a brief description of these concepts:

Presence

A consensus among many authors is that presence is a fundamental variable to understand virtual reality. Thus, the higher the level of presence, the greater the chances of the individual acting as if he/she were really there. (Slater and Usoh, 1996). Slater considers presence to be a state of consciousness, a psychological sensation of being in an environment. In this sense, a virtual class that causes high levels of presence is desirable in a guided tour aimed at learning architecture. Here, it was decided to adopt Rebelo's proposal (2012), that suggests the presence as a subjective concept, experienced by the user, related to the psychological state of feeling in the virtual environment, even if physically the user is elsewhere.

Degrees of Freedom (DoF)

This is a concept related to the mechanical limitations of the equipment. There are two types of degrees of freedom, a) 3 DoF and b) 6 DoF. In the first case (a) means that the user can rotate the head in three directions: horizontal, vertical, and inclined. In the second case (b) in addition to turning in the three directions, it is possible to perform displacements in the X, Y and Z axes, that is, in addition to the turns, it is possible to move to the right, left, backwards, forwards, lower up and get up. Thus, 6 DoF systems offer a more complete immersion experience, which contributes to increased presence levels. Therefore, for a guided tour of architecture, it is desirable that the system used is 6 DoF, which will give the user a greater feeling of being present in the virtual environment.

Multi-user VR and Metaverse

Multi-user virtual reality refers to the application of online communication systems so that two or more users can access the same virtual space at the same time, and in it, through avatars and in a synchronized way, they can observe, dialogue, and interact with each other and with the environment.

Metaverses are virtual worlds with more complex potentials, a kind of ecosystem that can involve various social relationships and daily activities, such as entertainment, teaching, production, financial exchanges, among others. (Sun, 2021). Its concept was initially developed in the 1990s by Neil Stephenson. Since then, the term has been extensively explored and today it is considered promising in many areas. In this sense, for the subject addressed in this article, it is understood that the term multi-user VR is better suited to the current application of VR for guided tours.

LITERATURE REVIEW

The first works involving virtual reality and architecture appeared at the end of the last century, for example Donath and Regenbrecht (1996, 1999), Chan (1997), Hill, Chan, and Cruz-Neira (1999), among others. Over time, the evolution of technology and its popularization, the following two decades were of great advance allowing the dissemination of VR in various fields, including in the teaching of architecture. An example is the work of Ângulo (2015), that applied immersive technology as a way to evaluate the sensations that the students' architectural projects could provoke in users. More recently new studies have explored VR as a pedagogical tool in the architectural field, especially in situations where visiting the site is relevant to the learning process.

Ibrahim et al (2021) investigated the effects of VR on architecture history learning. Students visited virtually famous buildings like Le Corbusier's Villa Savoye and Frank Lloyd Wright's Fallingwater. The experiment allowed to verify, among other things, that those who used the immersive environment obtained greater gains in knowledge when compared to students under traditional conditions. The experiment considered the individual access of students in VR. In 2021 Chan et al applied VR in remote teaching of architectural history. They rebuilt the Parthenon in Rome in a virtual environment. The researchers added interactive and audio-visual tools. From a sample of 68 students, they analysed variables such as: a) learning architecture, b) history, c) structural realism, etc. The results showed that the combination of the detailed scenario and audio narrations (synchronized with the user's point of view) provided a positive learning experience. It was also observed that students were able to accurately assess three-dimensional aspects such as the size and proportion of spaces (Chan, Bogdanovic and Kalivarapu, 2021). The experiment considered remote teaching, that is, outside the conventional classroom environment.

In Egypt, Ashraf Gaafar (2021) proposed the use of the metaverse in education about architectural heritage, that is, an immersive virtual reality with multiple users aimed at teaching architectural history. Like the present research, Gaafar suggests the use of avatars for interaction between users, but only in the case of distance learning, that is, when students are not present in the classroom.

As observed, there are several studies that discuss the use of VR in the context of teaching architecture, but the multi-user modality (with avatars) applied within the conventional classroom is still a recent resource, with wide possibilities for investigation.

RESULTS: THE FLOW PROPOSAL

The proposed flow was divided into 5 steps.

Step 01: The Choice of Equipment

It is proposed the use of two types of equipment for application in the classroom: a) the HMD connected to a PC or b) the HMD Standalone.

The first requires a monitor with keyboard on the table (the cabinet can be under the table), this will make the physical classroom resemble the computer labs, common in many faculties. The positive point of this VR equipment is the high image processing capacity, since most of the data is calculated on the PC's video card, allowing the use of models with a high level of detail. Nowadays it is possible to have this solution without cables connected from the pc to the HMD because the image can be processed and transmitted in real time, without delays, using wireless connections of the 5g type. For example, the oculus quest 2 gives this option. The negative point, as the name itself explains, is the need for a computer to control the glasses, this considerably increases the monetary value of the investment and forces the insertion of a monitor and keyboard on the table, reducing the free space for drawing. the hand.

The standalone HMD takes up little space, so it can be stored in a drawer under the table or even in a specific closet in the room. As it does not require a computer, it can be used in the same drawing room, making the original look of the teaching environment practically unchanged. The main negative point is the low processing power, which brings the need to optimize very detailed models so that they work properly. This optimization may require some time and knowledge of modelling and rendering on the part of those who prepare the virtual environment for the class.

Step 02: The Layout of the Room

To discuss the size of the physical space, we took the hypothetical example of a class composed of 16 students and a teacher. In the case of classes with a larger number of students, it is advisable to consider proportionally larger rooms, or divide them into two classes. To offer high quality of immersion and presence, in this investigation, the type 6 DoF HMDs were chosen as equipment, and there is one for each student.

Most HMDs, when starting their system, require the demarcation (in the real world) of an area free of obstacles for use, that is, a safe space for the user not to collide with objects or people that are nearby. This virtual limit is called Guardian by some manufacturers. This is necessary because by putting the glasses on the head, the user is fully immersed in the virtual environment, not realizing more clearly what happens around him in the real world, so without the existence of the Guadian, there is a risk of accidents. A minimum area already pre-configured on some equipment is equivalent to a circle with a diameter of 1.7m, this allows good safety so that a person can stand and fully open their arms in any direction. The positive point of this configuration is that in a room with several people, the occupied individual space will allow several movements. The negative point is the physical area of the room, because in the case of 16 students and a teacher will need about 75m2, already counted table and chair for each student and teacher.

Another option is to use a smaller guardian. In preliminary tests of the authors of the research, the distance of 1.2 m was experienced between the tables, this caused some students to push the chair back and use more efficiently the area in front of them. Although students often leaned against the chair, they showed some normality with space restriction, and remained focused on content. In the case of the example of the room for 16 students, an approximate area of $60m^2$ will be required. This measure is consistent with the space occupied by a virtual reality lab at the University of Sydney. They prepared an environment capable of receiving at least 21 people simultaneously for VR use, and the area used was approximately $95m^2$ (Ijaz et al., 2017). The positive point of this option is the optimization of space, the negative is the existence of some reduction in freedom of movement, but nothing that proves to be enough to compromise the experience.

Step 03: The Choice of Digital Models

The modelling of virtual environments for VR can be the same as for electronic models, that is, using software already known in architecture such as Sketchup, Revit, ArchiCAD, among others. However, in the case of virtual guided tours in historic spaces, many models are already available on specialized websites, some even free. As an example, the 3D Warehouse website is cited, which has famous models in architecture, such as the Fallingwater House by Frank Lloyd Wright, the Farnsworth House by Mies Van Der Roche, etc.

Step 04: The Choice of Software (Illumination, Rendering and Immersion)

Four programs/plug-ins that allow the use of VR in multi-user mode were analysed. The first two: @VRSketch and @Arkio, are applications aimed at the design of buildings, therefore with several tools related to architecture, such as material exchange, on-off layers, review notes, among others, also including a modelling system that favours the creativity process within the immersive environment. These applications can receive files directly from modelling software (such as Sketchup, Revit, ArchiCAD, etc.), the conversion is automatic and fast, and with just a few clicks, all students will be able to simultaneously enter the virtual environment and carry out the guided tour, including avatars. The main limitations of this type of application are a) the graphic, which is very simplified (no realistic finish) and b) the absence of programming resources, making it impossible to insert elements such as dynamic water texture, wind force, among others. Even so, it is reasonable to consider that such limitations are not essential for a virtual guided tour, therefore, it is understood that both are good alternatives due to their ease, speed, and practicality.

Another alternative is software intended for game programming, such as Unity and Unreal. Both have a very high learning curve and complex production flow, but the graphic quality is much higher, coming very close to the real world. They are programs suitable for those who have or wish to acquire knowledge about a programming language, allowing the inclusion of visual effects and interactions that can considerably increase the sense of presence. The main disadvantages are the high learning curve, the complex workflow, and depending on project demands the need for knowledge of the programming language. However, both software's have on their stores, available pre-programmed scripts and assets that allow you to add many interactions that make a deep knowledge of programming unnecessary.

On a plus point, the high-quality graphics, programming features and flexibility make the experience programmed into them potentially more interesting.

Step 05: The Realization of the Class with the Guided Tour in Multi-user VR

In line with the proposal of Ge (2019), it is understood as relevant to reserve a period for students to explore the building freely. The authors' experience shows that, if such time does not exist, it is possible for some students to do it on their own, momentarily dispersing themselves from the group and the objectives of the class. In the pilot tests carried out by the authors, it was observed that the class tends to flow well when the teacher starts using conventional tools (technical plans, photographs, and others), and after a general reading about the building, asks the students to place the HMDs. It takes about 3-5 minutes for the VR equipment software to launch, and for the student to access the correct application. After that, everyone starts to enter the virtual environment, to see their avatars and to interact with brief games. Faced with this scenario, the teacher can take the lead and continue the class.

CONCLUSION

The five stages presented result in achieving the proposed objectives, also the preliminary experiences of the authors indicate that VR in the physical classroom can be favorable in improving teaching, especially in the case of guided tours, but more studies need to be conducted aiming at the efficient use of technology. As for limitations, preliminary tests suggest that there are several elements in VR that require further studies for use in the classroom. One of them is the locomotion system, which, by allowing very fast movements, sometimes leads some students to get lost. Similarly, the sound system, which presented a considerable delay in relation to real-world dialogues, among others.

Finally, although it is considered here that the term multi-user VR is currently the most appropriate, the creation of popular and specific metaverses for education tends to be a common reality soon. In other words, complex virtual worlds in which there will be educational environments rich in details and self-explanatory, suitable for receiving teachers and students from all over the world, with no limit on audience, time, language, among others, potentially suitable for architecture, engineering, and other courses, including for use within physical classrooms.

ACKNOWLEDGMENT

Research funded by CIAUD Project UID/EAT/4008/2020 and ITI -LARSyS-FCT Pluriannual funding 2020-2023 (UIDB/50009/2020).

REFERENCES

Angulo, A. (2015) 'Rediscovering Virtual Reality in the Education of Architectural Design: The immersive simulation of spatial experiences', Ambiances [on-line], (September), pp. 0–23. doi: 10.4000/ambiances.594.

Chan, C.-S., Bogdanovic, J. and Kalivarapu, V. (2021) 'Applying immersive virtual reality for remote teaching architectural history', Education and Information Technologies. doi: 10.1007/s10639-021-10786-8.

Chan, C. (1997) 'Virtual Reality in Architectural Design', in CAADRIA 97 Workshops. HsinChu, Taiwan. Available at: https://www.researchgate.net/publication/272820335_Virtual_Reality_in_Architectural_Design/stats.

Donath, D. and Regenbrecht, H. (1996) 'Using Virtual Reality Aided Design Techniques for Three - dimensional Architectural Sketching .', in ACADIA Conference Proceedings, pp. 201–212. Available at: https://cumincad.architexturez.net/doc/oai-cumincadworks-id-656d.

Donath, D. and Regenbrecht, H. (1999) 'Using immersive virtual reality systems for spatial design in architecture', in AVOCAAD '99 Conference Proceedings, pp. 307–318. Available at: https://cumincad.architexturez.net/doc/oai-cumincadworks-id-fd35.

Gaafar, A. A. (2021) "'Use of Fully Immersive Virtual Reality Techniques to Generate Scale 1: 1 Interactive Models of Pharaonic Tombs"', 6, pp. 66–86. Available at: https://www.ss-pub.org/aeer/metaverse-in-architectural-heritage-documentation-education/.

Ge, Y. (2019) 'Teaching Research on "Experience" Architecture History with VR Technology', Frontier of Higher Education, 1(1), pp. 5–9. doi: 10.36012/fhe.v1i1.569.

Gomes, E. B. de O. et al. (2018) 'The Virtual Reality as a tool to analyze modifications in the architecture of the city. Case study: the historical center of the city of Belém-Pará.', in Blucher Design Proceedings. São Paulo: Editora Blucher, pp. 860–865. doi: 10.5151/sigradi2018-1412.

Hein, C. and van Dooren, E. (2020) 'Teaching history for design at TU Delft: exploring types of student learning and perceived relevance of history for the architecture profession', International Journal of Technology and Design Education, 30(5), pp. 849–865. doi: 10.1007/s10798-019-09533-5.

Hill II, L. C., Chan, C. and Cruz-neira, C. (1999) 'Virtual Architectural Design Tool (VADeT)', in Proceedings of the 3rd International Immersive Projection Technology Workshop, pp. 231–241. Available at: https://www.researchgate.net/publication/231513985_Virtual_Architectural_Design_Tool_VADeT.

Ibrahim, A., Al-Rababah, A. I. and Bani Baker, Q. (2021) 'Integrating virtual reality technology into architecture education: the case of architectural history courses', Open House International, 46(4), pp. 498–509. doi: 10.1108/OHI-12-2020-0190.

Ijaz, K. et al. (2017) 'The Immersive Learning Laboratory: employing virtual reality technology in teaching', AAEE 2017 (28th : 2017), p. 974. Available at: https://researchers.mq.edu.au/en/publications/the-immersive-learning-laboratory-employing-virtual-reality-techn.

Rebelo, F. et al. (2012) 'Using virtual reality to assess user experience', Human Factors, 54(6), pp. 964–982. doi: 10.1177/0018720812465006.

Slater, M. and Usoh, M. (1996) 'Presence: Experiments in the Psychology of Virtual Environments', 135th AES Convention. doi: 10.1.1.35.6637.

Sun, C. (2021) 'Architecting the Metaverse', ArchDaily Brasil. Available at: https://www.archdaily.com/968905/architecting-the-metaverse.

Vilar, E. et al. (2013) 'The influence of environmental features on route selection in an emergency situation', Applied Ergonomics, 44(4), pp. 618–627. doi: 10.1016/j.apergo.2012.12.002.

Vilar, E. et al. (2014) 'Effects of competing environmental variables and signage on route-choices in simulated everyday and emergency wayfinding situations', Ergonomics. Taylor & Francis, pp. 511–524. doi: 10.1080/00140139.2014.895054.

Zevi, B. (1996) Saber ver arquitetura. 5a Edi. São Paulo: Martins Fontes.