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Virtual reality technology in architectural education

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ABSTRACT: Contemporary virtual reality (VR) technology allows the recreation of non-existent architectural objects of which there may be no trace remaining. Virtual reality applications allow access to digital models, which visualise the lost architecture. The popularity of VR has resulted in it being applied not only to computer games, but also in visualising the past. Maps allow movement through historical trails and 3D models of architecture that no longer exist can be activated on tablets that allow topographic points of modern space to be overlaid with virtual perspectives of historical architecture. In the future, such technology will be applied to develop outdoor exhibitions in memorial sites. They are nowadays used by students during classes in architectural and urban design, so as to make the visualisation of design issues more interesting. The aim of this article is to review the possibilities of the application of VR technology in student projects in architectural education.

INTRODUCTION

The architectural design process has been transformed since parametric and algorithmic modelling tools were introduced. New technologies support architectural conceptual design, perform analyses and present ideas. Two decades ago, architects expected the support of the design process to be enhanced by digital tools:

> *Computers were introduced to the architectural profession with the hope that they would free architects of the mundane, manual tasks, as well as aid in the management of information* [1].

Today, the use of computer-aided design (CAD) software by the construction industries is no longer an innovation, but a necessity. This should be included in the standard didactic process of architectural design. Development of digital tools for parametric-algorithmic modelling is important for contemporary architectural design and education. Technologies have been developed that enable human-computer interaction in a digitally created sensory immersion environment. Among them, virtual reality (VR) applications are popular in which a computer generated image is interactively controlled by a user.

Virtual reality technology is evolving quickly - from static visualisations, through the presentation of 360° panoramic views to the presentation of parameters. Among developments is mixed reality (MR) technology enabling digital enhancement of real-world images. While VR technology provides users with the opportunity to experience the environment created through visualisations, MR enables the imposition of digital data on the real world.

The research presented in this article was focused on analysis of contemporary applications of virtual reality for architectural design. The evaluation indicated its effectiveness as an educational tool in the architectural design studio to improve learning. The main goal was to investigate how, and to what extent, students would benefit from VR in architectural design using the example of memorial places planning.

POTENTIAL OF VR TECHNOLOGY

Virtual reality is present not only in entertainment, but also in architectural design. The virtual reality aided design (VRAD) system is an area of interest for both practitioners and researchers of theory and architectural education [2].

It is also a topic that arouses interest among students. The results of a survey of students in the Faculty of Architecture at Gdańsk University of Technology (FA-GUT) to gauge interest in classes combining architectural design with VR indicated that 85% were interested (The study was conducted on a random, voluntary sample of 52 people, as part of lectures on Architectural Studio for the fifth semester of the undergraduate studies at the FA-GUT in 2019).

The introduction of VR into the design process in architecture initially raised doubts. The first issue was the use of complicated software. Difficulties in mastering it might discourage potential users. Hence, there has been an adaptation of software that is widely used in the construction industry. Most VR applications support 3D and BIM (business information modelling) file formats popular among architects; such applications include Revit, SketchUp and Rhino, 3ds Max, Navisworks and ArchiCAD [3].

The second problem was the cost of equipment needed to support VR, which was expensive in earlier times. Today, there are three main connection types: connections to computers, standalone devices and mobile phones [3]. These devices have a cable or wireless connection with special helmets or glasses, called a head mounted display (HMD). The VR applications have experienced significant transformations in recent years.

Displays, such as Oculus Rift, Samsung Gear VR, HTC Vive, Microsoft HoloLens and Google Cardboard, have introduced VR to the mainstream and made it more affordable for users. This makes VR more accessible to both practising architects and students. In addition, VR applications are available on many everyday mobile devices, such as smartphones and tablets equipped with high resolution screens, high computing power and motion sensors. The portability of these devices allows for applications anywhere [2].

Another interesting option for displaying VR applications is in immersive rooms: *Cave automatic virtual environment* (CAVE) is a room surrounded by screens on all sides. This is a costly solution for educational institutions but highly inspiring. According to research conducted at the FA-GUT, the presentation of visualisation of architectural concepts in the Immersive 3D Visualisation Laboratory (I3DVL) offers: ability to choose any frame; ability to choose any frame by recipient; ability to view variable visual effects in real time, from real distances; ability to visualise interactive installations in real time; and verification of design assumptions [4].

More and more architects are incorporating virtual reality into the design process. Along with technologies that complement VR capabilities, i.e. augmented reality (AR) and mixed reality (MR), virtual reality provides designers with new ways to experience and understand a building or space before it is actually built.

As a result of research and implementations carried out over the past two decades, several areas of architectural design have been identified for the use of VR, as well as activities in the construction industries. The most important include:

- a new way of visualisation with immersion in virtual reality;
- improving communication in the co-ordination of construction projects between designers, contractors and investors [2];
- ability to obtain the final image of the project during various stages of the design process [5];
- strengthening participation in the design process and the ability to involve future users of the designed objects to take part in the creation of the final design [6];
- possibility of more efficient and accurate prototyping of design solutions by replacing the physical model with VR visualisation and reducing the cost of prototype production on a 1: 1 scale [7];
- optimisation of the construction process and reduction of the level of design defects at the execution stage [8], because the technology enables onsite visualisation for construction planning and as-built verification [2];
- better understanding of the structure at the final design stage [9].

Despite the popularity of VR technology in the designer's environment, it is sporadically used in architectural education. In 2016, CGarchitect conducted a survey among its members on VR technology in professional activities. The answers from all over the world show that the most common users are the employees of Architectural Visualisation Studio: 43%, and architectural firms: 22%. For educational purposes, only 2% students and 1% of academics (teacher, professor, researcher, lecturer) declared they would use the technology [10].

However, this does not mean that this is an area not recognised in architectural education research. In the current literature, there are several review articles referring to architectural design classes with advanced digital applications.

Virtual reality technology has been applied in student education since the 1990s [9]. In the first attempts, it was used as an environment to support design with creative and innovative potential [11]. Many systems tested by design students (in the discipline of architecture or interior architecture) took into account the impact of VR on education rather than on the design process itself [2]. These studies were focused on the benefits of VR technology to improve students' skills; they concerned:

- understanding a structure and its construction [12];
- remote co-operation of design students [13];
- integration of VR with the curriculum of design courses in architecture schools [14];
- individually setting the platform and software depending on the needs of students, both in terms of design and communication [15];
- implementation of the combination of VR, BIM and AR technologies that can provide alternative data representation options [16].

Virtual reality supports gaining knowledge through learning based on experience. Virtual reality is a technology that replaces real-world sensory data with sensory data created by computer simulation. It helps in teaching by providing an environment that allows users to experience scenarios and situations instead of imagining them [9]. Until recently, the key argument inhibiting the presence of VR in education of architectural design was the cost of purchasing technology-related equipment and the difficulty of acquiring skills to operate it [1].

Today, students are fluent in the application of CAD software and graphics processing applications. There is an increased mastery of software among the modern generation of students. Young people have become familiar with the operation of IT devices since childhood and, therefore, the combination of digital technologies with education seems a necessity [17]. Students who have experience in computer modelling are becoming increasingly familiar with VR, which helps promote changes in both education and architectural practice.

As mentioned earlier, a questionnaire was distributed to students to register comments and opinions on advanced CAD technology skills and the degree of interest to participate in classes combining architectural design with VR. The study was conducted on a random, voluntary sample of 52 people, as part of lectures on Architectural Studio for the fifth semester of the undergraduate studies in the FA-GUT, in 2019. The results of the survey show some students (29%) acquired skills in graphic software before starting education at university (Figure 1).

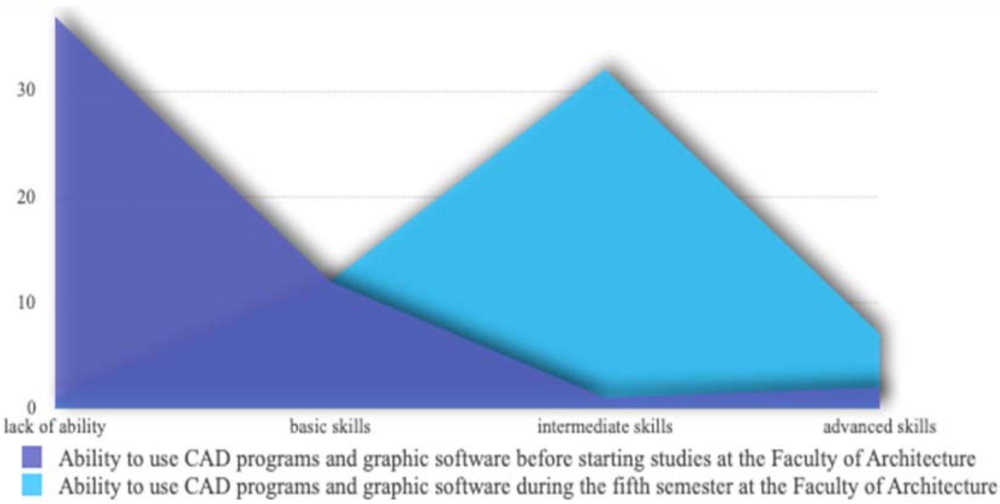

Figure 1: Skill-level of the use of graphic programs before and during study at the Faculty of Architecture (Source: Author).

Most students declared a significant increase in skills as a result of study classes (44%) and their own interests in the subject (69%). The most popular programs included AutoCad (71%), SketchUp (61%), Adobe Photoshop (60%), Autodesk Revit (35%), CorelDraw (25%) and Lumion (19%) (see Figure 2).

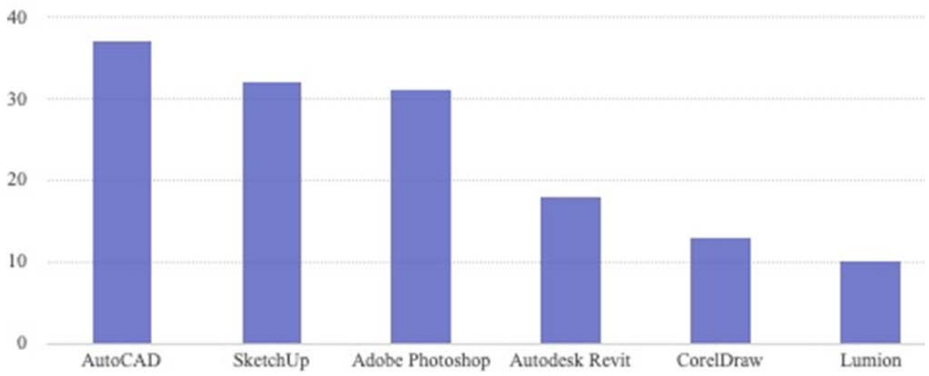

Figure 2: The most popular graphic programs among students of the fifth semester at FA-GUT (Source: Author).

DESIGN PROCESS

The most important motivation for producing this article is that VR can create a virtual architecture in place of the real one. Interactive technologies are now becoming an important architectural tool in creating sensorially rich architecture and living public spaces [18]. There is a growing interest in VR in the reconstruction of historic places. In the present century, digital technologies can reveal the past in areas associated with important historical events. Hence, VR can help to understand the past and provide access to a wider range of historical knowledge. Applications for mobile phones or tablets allow access to augmented reality (AR): a system overlaying the real world with computer-generated data. A visual collage is created that helps the contemporary viewer get closer to historical times. With the help of new technologies, it is possible to create new educational paths through historical areas. Virtual reality applications enable virtually reconstructed buildings in situ. It is a solution associated with low cost and with no controversy, which the reconstruction of historical buildings usually arouses.

At the FA-GUT, virtual reality technology mainly is used to support the presentation of architectural concepts prepared as part of Master's degrees. An interesting example is the diploma proposed by Szymon Kowalski entitled, *Protection of Historic Landscape of the Battle Field. Open Air Museum of Westerplatte*, made under the supervision of Prof. Jakub Szczepański. It embraces virtual reality technology not only as a medium for presentation, but also as an ideological concept representing VR as a tool supporting architectural objects in the exhibition of historical events (Figure 3 and Figure 4).

Figure 3: Diagram of VR technology in the design of historical exhibition paths. Source: *Protection of Historic Landscape of the Battle Field. Open Air Museum of Westerplatte*. Szymon Kowalski's diploma project, Gdańsk University of Technology, 2019.

Figure 4: Examples of frames presented in points on the exhibition paths of historical events. Source: *Protection of Historic Landscape of the Battle Field. Open Air Museum of Westerplatte*. Szymon Kowalski's diploma project, Gdańsk University of Technology, 2019.

Virtual reality technology allows architectural design classes based on advanced digital technologies, enabling a broader understanding of concept visualisation. An elective subject has been in the education programme in the FA-GUT since 2010, called, *A Place of Memory as an Architecturally Organised Space*. As part of the classes, students of the fifth semester learn the characteristics of contemporary commemorative architecture represented by monuments, monument assumptions and museums. The students prepare a project of their own commemorating objects in historic areas.

The elective subject expands the educational method by conducting classes in design that include trends in VR technology. When defining a problem and conceptual design, students can choose any medium that is helpful. At this stage, students create preliminary concepts for their projects.

The resulting concepts will create digital models in a form that allows use in VR applications. In the design studio, there will be lectures and presentations explaining to students how to import and export digital models and how to use the main functions of the VR program. The VR program is applied in student projects in the next stage after almost completing the concept. Audio-visual content regarding the reconstruction of historical objects and related infrastructure prepared by students can be displayed at appropriate topography points.

Virtual reality is able to support the design of commemorative places by applying reconstructed buildings to the real image. Realistic concept visualisation enables students to experience the spatial consequences of proposed solutions. It also allows the development of additional skills for designers' future work.

Representing the past is consistent with modern trends in teaching monument preservation. New trends are evident in education for young architects: *…students are being taught how to consciously use the existing limited resources of the environment and space, as well as cultural goods* [19].

CONCLUSIONS

The introduction of virtual reality to classes in the conservation of monuments or designing commemorative architecture combines aspects of the past with a contemporary understanding of the world, while respecting history and heritage. The synergy of contemporary technological development and historical knowledge provides an opportunity for students to prepare for the growth of digital technologies and, what is more important, to acquire additional competencies fit for their future careers.

REFERENCES

1. Cambell, D.A. and Wells, M., A Critique of Virtual Reality in the Architectural Design Process. Technical Report: R-94-3 (1994), 24 October 2019, *http://www.hitl.washington.edu/publications/r-94-3/*
2. Milovanovic, J., Moreau, G., Siret, D. and Miguet, R., Virtual and augmented reality in architectural design and education: an immersive multimodal platform to support architectural pedagogy. *17th Inter. Conf., CAAD Futures* (2017).
3. Huang, Y., Shakya, S. and Odeleye, T., Comparing the functionality between virtual reality and mixed reality for architecture and construction uses. *J. of Civil Engng. and Architecture*, 13, 409-414 (2019).
4. Życzkowska, K. and Urbanowicz, K., Architectural education and digital tools: the challenges and opportunities. *World Trans. on Engng. and Technol. Educ.*, 17, **3**, 326-331 (2019).
5. Behzadi, A., Using augmented and virtual reality technology in the construction industry. *American J. of Engng. Research*, 5, **12**, 350-353 (2016).
6. Petrova, E., Rasmussen, M.B., Jensen, R.L., and Svidt, K., Integrating virtual reality and BIM for end-user involvement in design: a case study. *Proc. Joint Conf. on Computing in Construction (JC3)*, Heraklion, Greece, 699-706 (2017).
7. Fuchs, P., Moreau, G. and Guitton, P., *Virtual Reality: Concepts and Technologies*. London: CRC Press, 339-361 (2011).
8. Asgari, Z. and Rahimian, F.P., Advanced virtual reality applications and intelligent agents for construction process optimisation and defect prevention. *Procedia Engng.*, 196, 1130-7 (2017).
9. Abdelhameed, W.A., Virtual reality use in architectural design studios: a case of studying structure and construction. *Procedia Computer Science*, 25, 220-230 (2013).
10. Mottle, J., Survey Results: VR Usage in Arch Viz (2016), 15 October 2019, http://www.cgarchitect.com/ 2016/07/survey-results-vr-usage-in-arch-viz
11. Achten, H.H. and Van Leeuwen, J.P., Feature-based high level design tools: a classification. In: Augenbroe, G. and Eastman, C. (Eds), Computers in Building. *Proc. 8th Inter. Conf. on Computer Aided Architectural Design Futures*, 275-290 (1999).
12. Garcia, A.R., Marquez, J. and Valverde Vildosola, M., Qualitative contribution of a VR-system to architectural design: why we failed? *Proc. 6th Conf. on Computer-Aided Architectural Design Research in Asia*. Sydney, Australia, 423-428 (2001).
13. Lang, S. and Hovestadt, L., An architectural framework within a spatially immersive real-time environment for advanced communication and collaboration. *21th eCAADe Conf. Proc.*, Graz, Austria, 37-43 (2003)
14. Kieferle, J.B. and Herzberger, E., The *Digital year for Architects* experiences with an integrated teaching concept. *20th eCAADe Conf. Proc.*. Warsaw, Poland, 88-95 (2002).
15. Kalisperis, L.N., Otto, G., Muramoto, K., Gundrum, J.S., Masters, R. and Orland, B., Virtual reality/space visualization. Design education: the VR-desktop initiative. *20th eCAADe Conf. Proc.*, Warsaw, Poland, 64-71 (2002).
16. Morton, D., Augmented reality in architectural studio learning: how augmented reality can be used as an exploratory tool in the design learning journey. *Proc. of the 32nd eCAADe Conf.*, Newcastle upon Tyne, UK (2014).
17. Aldwairi M. and Shuhaiber, A., Exploring the integration of CDIO, crowdsourcing and gamification into information security courses. *World Trans. on Engng. and Technol. Educ.*, 17, **3**, 237-243 (2019).
18. Urbanowicz, K. and Nyka, L., Interactive and media architecture - from social encounters to city planning strategies. *Procedia Engng.*, 1330-1337 (2016).
19. Szczepański J., Sustainable monument preservation in architectural education. *World Trans. on Engng. and Technol. Educ.*, 17, **1**, 42-47 (2019).