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Virtual Reality and Building Information Modeling in Architecture

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Abstract

This article explores the integration of technologies, particularly Information and Communication Technologies (ICTs), in the field of Architecture, Engineering, and Construction (AEC), with specific emphasis on the Brazilian context. In a globally interconnected society, the adoption of ICT has reshaped traditional practices, promoting new modes of interaction and dissemination of knowledge. AEC professionals are transitioning from knowledge holders to mediators, facilitating the collaborative construction of knowledge. Despite challenges such as uneven technological adoption, Brazil is witnessing a rapid expansion in the use of technology in the educational and professional sectors. The COVID-19 pandemic has accelerated the computerization process, highlighting the importance of technology in several industries, including Architecture. The article investigates the transformative potential of Building Information Modeling (BIM) and Virtual Reality (VR) technologies in architectural practices. BIM, a multidimensional virtual model that integrates geometric and construction data, revolutionizes collaboration between architects, engineers, and builders, streamlining the flow of information and enhancing visualization capabilities. VR complements BIM by offering immersive simulations, facilitating a deeper understanding of architectural designs throughout the entire project lifecycle. The study investigates how BIM and VR tools improve the understanding of architectural design from conception to construction, addressing key implementation considerations and the evolving role of professionals in adapting to technological advances. Through empirical analysis, the article elucidates the tangible benefits and challenges of adopting these technologies in AEC, paving the way for more rigorous and efficient design, planning, and project management processes. Immersion in the virtual environment with the participation of architects and engineers was carried out. The modeling of a real residence using the oculus was developed. The results point to the innovation achieved using virtual reality and BIM for AEC.

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1. Introduction

Technology has been one of the solutions to overcome the challenges of a country with large areas and possibilities for major transformations like Brazil. In this paper, the technology's application domain is focused on the area of Architecture, Engineering and Construction (AEC) and those who are directly or indirectly involved in the process.

In a globalized world, the process of interaction with the social, cultural, economic and political environment directs us to look at the reality in the world where we can establish connections across borders, in a model focused on development and new arrangements and partnerships. Information and Communication Technologies (ICTs) in recent decades have presented new ways of interacting and disseminating information. New attitudes, new ways of thinking, and new attributes to carry out activities, combined with economic growth, stimulate and demand improvements in the quality of the AEC system.

In general, many areas are being led to think about new themes and bring reflections to their production environment. The professional, holder of knowledge, has been replaced by a mediator and stimulator of criticism who collaborates with the construction of knowledge.

In recent years, spaces intended for the profession of architecture have experimented with often complex forms and attempts to change the process of making Architecture. From technological advances, the ways of making architecture became an experienced reality, fueling an evolution not only regarding the use of technological tools but also modifying behaviors.

Some countries, such as Brazil, still have basic problems with the use of technology. Universities are expanding the installed base at great speed and on a large scale as the country invests in expanding the scope of use of technology in basic education. Professionals and companies gradually expand the use of technologies with possible limitations and challenges. Using BIM and VR can have significant obstacles, such as resistance to business model change and high costs of implementing, updating, and maintaining software and hardware. Companies need to understand the barriers to adequately plan and budget the use of technologies, as well as develop strategies to reduce these challenges. BIM and VR technologies require training and skill development for both new users and experienced professionals. Interoperability between different systems and software when using BIM and VR technologies is a challenge. Solutions that have compatibility between systems and data integrity and encourage collaborative practices between software developers and users are essential.

The critical period of the COVID-19 pandemic was marked by several transformations in society, leaving a consequence reflected in the changes in the process of accelerating the process of computerization and development of ICTs in different areas. This topic is too broad to be treated in its entirety, but changes and advances in aspects related to Architecture can be inferred.

With the evolution of software and its adaptation to needs, the way professionals use these tools to create and develop an architectural project also changes. The use of these technologies in civil construction, in the training and performance of Engineers and Architects, requires profound changes in the production of architectural objects.

BIM and Virtual Reality technologies applied to the development of architectural projects are used to experiment and prove how immersion can improve the architect's craft, the client's vision, and the interaction between the professional who develops the project and the client who represents the user of the object. architectural.

BIM technology is one of the most promising developments in the architecture, engineering and construction industry. A three-dimensional virtual model of the building is constructed and contains, in addition to the geometry, various relevant data and information necessary for construction, manufacturing and other activities to carry out the construction. Technology integrates architects, engineers and builders, changing and streamlining the information cycle, being an evolution that allows new possibilities for visualization, processing, representation, use and retrieval

of information [1], [2]. BIM technology is considered an evolution of graphic applications aimed at generating technical drawings (CAD) [3]. Characteristics and recommendations for the implementation and better use of BIM technology are extensively discussed in [4].

The objective of making the design, planning and management of the work more rigorous and faithful to what will be built uses Virtual Reality (VR) to simulate the environment and provide a true understanding of the built environment.

In this context, the research question arises as to how BIM and Virtual Reality tools can improve the understanding of architectural design from conception to construction.

2. Theoretical Foundation

The foundation is based on concepts of 3D three-dimensional modeling, VR, and BIM that are transforming the way we interact with the physical and digital world, providing more immersive and efficient experiences. The applicability of these tools has been expanding exponentially not only in various disciplines but also in architecture and engineering.

2.1. The project

The design process of an architect or engineer is complex and involves multiple steps. While each architect or engineer may have their unique approach, common phases typically occur. These stages include defining the problem, brainstorming ideas, developing concepts, conducting preliminary studies, detailing the project, creating technical documentation, collaborating with complementary professionals, presenting the project to the client, and overseeing the work's progress. The creation of the architectural project is based on the creative process, understanding the context, responding to the client's needs and solving design problems in addition to the tool used to design it. Tools such as pencils, paper, computer-aided design (CAD) programs, or 3D modeling are means by which architects express and communicate their ideas. The choice of tools may vary depending on the architect's preferences, project complexity and specific requirements. Many architects use traditional and digital methods at different stages of the design process.

2.2. The graphical representation

During the last decades, the process of transition from architectural design carried out in a manual process to the use of computer-aided design (CAD) has been experienced. Then we changed the project developed in 2D to parametric projects in 3D with new technologies that allow integrated work between geometric models and information. The platforms have advanced project development forms, allowing collaborative work, interoperability, use of databases, intelligent objects and more user-friendly interfaces. Among the advances of this change, we can highlight the three-dimensional simulation of the environment based on computer graphics methods and technologies. The immersion in virtual environments with virtual reality and the use of glasses and other devices with sensors for total immersion. in the virtual environment [5].

BIM technology arises for the development of the information system integrated into all stages of development in the AEC area. Going further, the use of immersive technologies such as Virtual Reality (VR) has become more widespread in AEC allowing for more realistic visualization and immersion of projects.

Technology can also be seen as an element of socialization and innovation, which needs to be informed, taught and learned, as it will be incorporated into the human universe, expanding their knowledge and making them more qualified [6].

2.3. Building Information Modeling - BIM

The use of the Building Information Modeling (BIM) system as a learning and knowledge production tool in building design encompasses the dissemination of the use of information technology in different areas of knowledge and the new possibilities of representation and simulation of architecture and construction [1].

BIM (Building Information Modeling) has become a process facilitator for architecture, engineering and construction (AEC) services. With BIM technology, accurate virtual models of a building are built digitally, which supports all phases of the project [2].

BIM proposes to redistribute the allocation of efforts, emphasizing the design phase of a project, where the main decisions are made. It covers methods that guarantee integration between drawings, allowing analysis and verification of models, with visualization and communication at different scales and project stages. It is a revolutionary concept in transforming architectural representation by replacing 2D drawings with parametric 3D models. These changes are affecting the way designers think and the processes they carry out. Even at an early stage, BIM is redistributing the time and effort that those involved spend on different aspects and stages of the project.

Architects and designers can use VR and BIM technological tools to improve the understanding of projects. By integrating these technologies, they can significantly improve the understanding of projects, promoting collaboration and more detailed analysis between disciplines, which can result in more efficient projects, with more informed decision-making.

During the building design, construction and operation development cycle, BIM can be applied to various uses. When deciding to adopt BIM, the project office must determine what objectives it intends to achieve with the use of technology, both from the point of view of improving the office's internal process and providing differentiated services and products to its clients [7].

2.4. Virtual Reality - VR

Virtual Reality is a term that generates disagreement in terms of answering how a virtual environment could be real at the same time. Are virtual environments, at the same time, real? Does the virtual reflect the real, does the virtual exist independently of the real? Divergent nomenclatures define what is virtual and what is real. They are different, alternative realities, created artificially, but which are perceived by our sensory systems in the same way as the physical world around us: they can excite, give pleasure, teach, entertain and respond to our actions, without needing to exist in a tangible form. (playable). Even materiality is beginning to be part of virtual environments, making them less and less distinguishable from “real reality” [8].

Virtual reality represents an interface at the intersection between technology and human experience. Its potential is vast, and its implementation requires a careful approach to address ethical challenges and ensure it benefits society. As we explore the limits of virtual reality, we are shaping not only how we interact with technology, but also how we perceive and experience the world around us [8].

The term Virtual Reality (VR) was developed in the late 1980s by Jaron Lanie [9], an artist and computer scientist who managed to converge two antagonistic concepts into a new and vibrant concept, capable of capturing the essence of this technology: the search for the fusion of the real with the virtual. However, the first proposals appeared before the definitive name and the first results that supported Virtual Reality. This requirement arises from increasing levels of project complexity, integrated delivery methods and the growing adoption of BIM in the construction [10].

3. Methodology

This research is conducted methodologically through the Design Science Research (DSR) approach, aiming to facilitate effective collaboration with the organizations selected to develop the study. DSR is an approach that focuses on solving real-world problems through the design, development, and evaluation of artifacts or solutions [11].

Professionals involved in the construction process throughout the life cycle of a building can obtain a comprehensive understanding of the project through the information contained in the geometric model. In addition to simplifying and speeding up the civil construction process, these geometric modeling and information tools have the potential to elevate individuals' creativity to new heights. The biggest challenge to be overcome is the barrier of thinking that features and tools could reduce individual creative capacity. On the contrary, making the individual's creativity flow and increase depends only on overcoming their difficulties to qualify for the use of the BIM methodology. Another issue to overcome is the change in thinking and procedures during the transition of the design process, moving from a two-dimensional model to a realistic three-dimensional model. This transition requires a

change in the way of thinking about the design and construction of the information and data model generated from the direct integration between design, simulation and reality.

3.1. Mapping

In the first stage of the research, guidelines and the state of the art in teaching and using software were studied and analyzed. Data for the study was collected from two sources, a survey among architects, engineers, and design professionals using an online questionnaire (Google Forms) was shared in a WhatsApp group of professionals in the AEC area, and 80 professionals responded. These professionals were able to write their own opinions and make suggestions. A face-to-face experiment among architecture and engineering students at UFMG with 60 students.

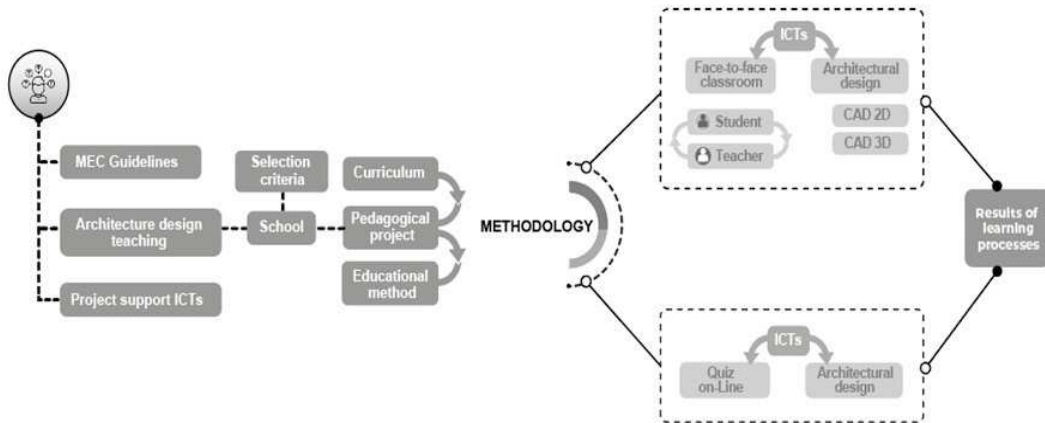


Fig. 1. 1o Cycle - Mapping.

Were listed some software to collect information on which one is used the most. The adoption of the AutoCAD platform maintains the leadership. It can be inferred that it was a natural process due to its widespread use in the Architecture, Engineering and Construction (AEC) industry globally. The Federal University of Minas Gerais (UFMG) was a pioneer in Brazil when it established, in 1997, a cooperation agreement with Autodesk to obtain free AutoCAD and other software. Then there is the use of 3D modeling by Autodesk Revit. The results of the first cycle of research indicate that the majority used CAD software still in 2D representation and BIM software with 3D representation (Fig 2.).

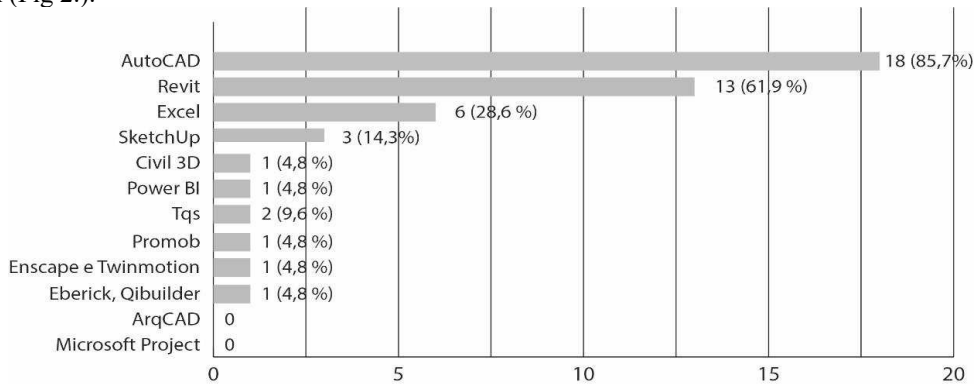


Fig. 2. Software used.

3.2. The Experiment

In the second cycle of this, an experiment using tools that allow experiencing the creation of an architectural project in 3D modeling and virtual reality. First, 3D modeling in the process of creating and defining the architectural project was developed. The object of the experiment is a house that will be built in the Alphaville neighborhood, in Nova Lima, Minas Gerais, Brazil. The high-standard house was designed for a family of 4 people. 3D modeling was presented as a resource for the final visualization by the client to demonstrate the spaces and the project design with finishing materials (Fig. 3).



Fig. 3. Different angles of 3D modeling.

The immersion that allows you to experience the architectural project in virtual reality was carried out (Fig.3). After creating the house and 3D modeling in Revit, the environmental configurations were made, preparing the Virtual Reality environment. The most appropriate Virtual Reality tool was selected considering the hardware, software and compatibility with the goals of the experiment.

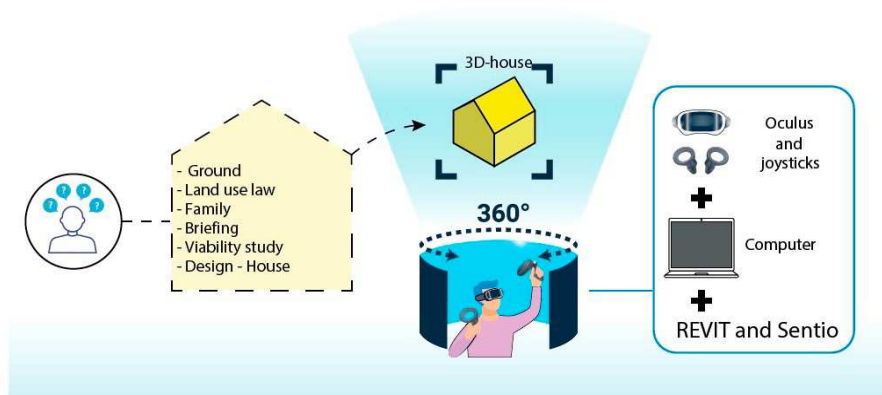


Fig. 4. 20 Cycle - Experiment.

The experiment was carried out in the Transcolar laboratory of the Faculty of Engineering of UFMG. In this initial experiment, two architects, an engineer and two engineering students participated, who were immersed in the house through virtual reality in real-time. At this stage, the group is restricted to make the methodology viable and ensure detailed monitoring of the participant's interaction with the virtual environment. Data was collected and detailed throughout the task, allowing an assessment of technologies in the AEC (Architecture, Engineering and Construction) process. Based on the results and validation of the methodology, it will be possible to expand it to larger groups. A more complete analysis will be possible and greater identification of new insights into the application of BIM and VR technologies in the AEC sector.

For immersion in virtual reality, the Meta Quest 3 headset was used, which allows the connection between virtual reality glasses and other devices such as a computer and smartphone connected to the same Wi-Fi network. This connection was made through the Meta Quest resource on the Oculus website, by creating an account that allows data to be shared from the computer's desktop with the virtual environment of the Meta Quest 3 headset. The camera

function configuration in the glasses' internal menu was used to mirror the vision of the glasses' virtual environment on other devices such as computers or smartphones. Next, the edge is defined that corresponds to the delimitation of the physical space of the laboratory mapped by the glasses, creating the virtual space.

Sentio plugin within the Revit program to upload the 3D model in 360 tours in the Sentio application was used considering that it was previously installed in the virtual environment of the glasses. The synchronization of data sent from the plugin to the glasses' virtual environment is done using a code linked to Sentio account, which can be verified on the website.

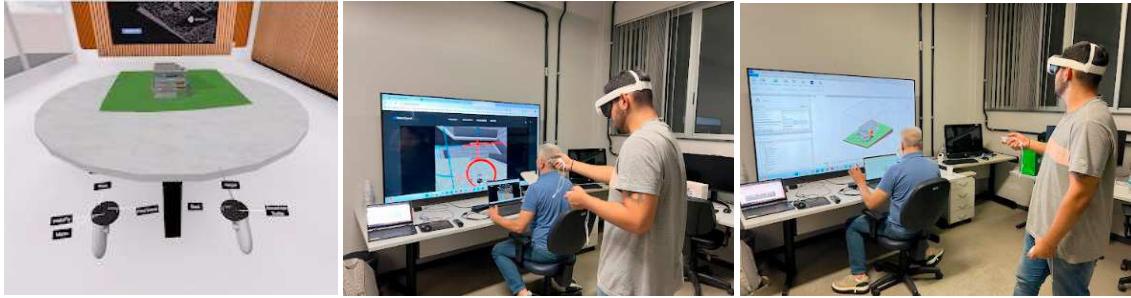


Fig. 5. Mirroring 3D modeling in Revit viewed through the headset

Walkthrough in the immersive environment uses commands from the Sentio application itself that allow you to walk, transport, fly and approach objects in the exported 3D model.



Fig. 6. Virtual Reality arriving at the house and walking inside the house

4. Final Consideration

Under the objectives of this research, it can be stated, through the results, that the virtual reality immersion environment with BIM technology has the potential for innovation in the AEC area.

The possibility of immersive participation by the architect, engineer and client in the virtual environment provides an experience within the architectural object to be built. A better understanding of the object supports more informed, more effective decision-making. Immersion offers a more realistic representation of the project, with the use of VR tools, through proportions, shapes and details, making them more understandable and more convincing for all interested parties, even if they do not have technical knowledge.

The possibility of visualization and compatibility of projects in the BIM environment, with three-dimensional modeling of the architectural project and complementary projects and, subsequently, the experience within the environment can generate savings in several stages, both in time and resources. Virtual Reality allows you to identify potential problems with more assertive decision-making.

These technologies are accessible in the academic and professional environment in a restricted manner, still with little use, specifically in Brazil. Challenges and obstacles that the academic environment and companies may face with BIM and VR include high costs, large investments, and resistance to changing the business model in

organizations. The time and effort required for academics and professionals to learn how to use these new technologies efficiently requires training that can be time-consuming and challenging. Interoperability issues can lead to difficulties in exchanging information and data between different platforms, resulting in loss of information, errors and rework.

The possibility for the architect to discuss and model the client's proposals in real-time, can iteratively participate in the design process, adjustments and definition of materials in the 3D Revit model. A safer solution is possible by enhancing the client's and the professionals' expectations and satisfaction.

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