Civil Engineering and Architecture 10(6): 2754-2763, 2022 http://www.hrpub.org
DOI: 10.13189/cea.2022.100638

The Use and Challenges of Virtual Reality in Architecture

Leenah Fakahani*, Sara Aljehani, Rahaf Baghdadi, Abdel-Moniem El-Shorbagy

Department of Architecture, College of Architecture and Design, Effat University, Qasr Khuzam St., Kilo. 2, Old Mecca Road, P.O.BOX 34689, Jeddah 21478, Saudi Arabia

Received September 15, 2021; Revised March 15, 2022; Accepted April 19, 2022

Cite This Paper in the Following Citation Styles

(a): *[1] Leenah Fakahani, Sara Aljehani, Rahaf Baghdadi, Abdel-Moniem El-Shorbagy , "The Use and Challenges of Virtual Reality in Architecture," Civil Engineering and Architecture, Vol. 10, No. 6, pp. 2754 - 2763, 2022. DOI: 10.13189/cea.2022.100638.*

(b): *Leenah Fakahani, Sara Aljehani, Rahaf Baghdadi, Abdel-Moniem El-Shorbagy (2022). The Use and Challenges of Virtual Reality in Architecture. Civil Engineering and Architecture, 10(6), 2754 - 2763. DOI: 10.13189/cea.2022.100638.*

Abstract Technology has changed so much over the years and it has contributed a lot to the advancement of the many aspects of the industry as well as people's daily life. Architecture is not spared from this change and has benefited a lot from the development of this technology. With this, it is no secret that one aspect of technology that has changed the world is virtual reality. This study outlines the application of virtual reality in various sectors such as industrial, architecture design, science and technology, education as well as entertainment. There is a great potential of virtual reality in the future, especially in two different aspects namely technological and social. The importance of virtual reality in architecture is relying on the advancement of technologies, applications and processes. The use of virtual reality in architecture can be classified into several categories, namely landscape, building, interior, and exterior. Moreover, this study also elucidates the challenges of virtual reality in architecture and education. All in all, the virtual reality in architectural highlights the multiple advantages of multiple applications, and overcomes the defining challenges which may lead to the successful realization of virtual reality in architecture.

Keywords Virtual Reality, Architecture, Science, Technology, Applications, Processes

1. Introduction

The term of virtual reality originates from 'virtual' and 'reality' which suggests that it is 'near-reality' [1]. It is another version of reality that is not really there because it is just made possible by technology so people can perceive it as real. The computer technology made this virtual reality possible and the images are motions coming from. In technical terms, this virtual reality would be described as a "three-dimensional, computer generated environment" [1]. Due to its three-dimensional feature, it almost looks real to the perception of the human eye and the person would see himself part of that world and immerse himself in that environment and he could see it as real since he could manipulate the environment.

Virtual reality can trace back its roots not when computers emerged but even before that when panoramic paintings, or the 360-degree murals were created to fill the entire vision of the person viewing it and view it as "almost" real and the person would feel that he is present in that event or scene [2]. This dates back in 1838 when Charles Wheatstone made a research about three-dimensional images and created the stereoscope for virtual tourism. This is the same design and principle that Google used today for the Google Cardboard. In 1849, the stereoscope was developed by David Brewster and it became a lenticular stereoscope. After 90 years, William Gruber came up with the View-Master to create a virtual reality.

All the developments along the centuries passed that would later on pave the way for virtual reality which proved that technology continues to evolve and people use this technology to further stimulate the senses of the people using it so they would perceive it as real. This technology continued to develop in the 20th century with the advent of computers and the modern technology that comes with them. This virtual reality then contributed much to flight simulations, science fiction story predictions, theatres, artificial reality, until the time came that the term 'virtual reality' was born in [2].

Now in the 21st century, virtual reality has evolved and branched out to different types which include enhanced reality, desktop virtual reality, telepresence, immersive virtual reality, and QTVR [3]. With these different types, come different uses of virtual reality in various fields that make it an inevitable force that can change and shape the future. This can be of most benefit to the fields of medicine, business, architecture, and manufacturing. In the field of medicine, virtual reality is used by psychologists and other medical professionals to aid in finding solutions for the treatment of PTSD and other behavioral and social disorders (Cicero). Virtual reality is also a big benefit to the car manufacturers as this helps them create and design safer models faster and in a more efficient way. Furthermore with the use of virtual reality, architects can now construct stronger buildings by building virtual reality models first to view its design instantly and test the design for its different capabilities. In addition, virtual reality technology can also be used for the virtual reconstruction and recording of historical urban heritage, which is a precious wealth of mankind and reflects the achievements of past dynasties [4]. Virtual reconstruction hopes to provide similar values and connotations to the physical environment, so that it can understand the production and consumption patterns of the physical environment, as well as its cultural, social and economic priorities and context [5].

In the field of architecture, the computer-generated images help architects replace the traditional way of hand-drawn designs with three-dimensional designs that would represent the buildings as if they have been built in the real world. This tremendously reduces the time spent on creating designs since computers would make it fast for the architects to create different designs that suit their taste and style. Additionally, the lighting fixtures are also easily simulated as if they are lighted in the real world and this makes it possible for architects to select the ideal positions and designs of lighting fixtures for buildings and spaces. As a result, architects could see the outcome or how the buildings would look even before the buildings are built.

With the capabilities of virtual reality, it becomes a tool for architects and other professionals to help them create a prototype and develop their designs more effectively. As whole, virtual reality also becomes a tool for construction companies to fast track their construction with the aid of computer-aided designs and simulations that gives more confidence to the quality of the structure being built (Brouchoud). It is not only the building structure that makes use of virtual reality as a tool for a prototype or visual designs, but the interior and exterior designs of buildings also make use of this tool for better outcome. Additionally, virtual reality is also used as a tool to develop towns and simulate how the town would run or appear with the new concepts and designs made possible by virtual reality.

Meanwhile, there are still challenges that affect the use of virtual reality in architecture and other areas in which it is applied. In the field of architecture and construction, and the use of virtual reality to create models, the term augmented reality is also used which refers to the blending of virtual reality and real life. There are three main challenges in this area which include (1) extraction of knowledge in the industrial field, (2) preparation of the real scene model, and (3) technical limitations [6].

With so much information being represented in software that helps build virtual reality, extraction of industrial domain becomes a tedious task. Thus, when it comes to integrating 2-D to 3-D models, the challenges arise as there are hidden objects in 2-D that must be included in 3-D models but the database might not include the information of all the locations where the hidden objects would be placed.

Another challenge is the preparation of reality models. Knowing that the virtual reality would mostly be based on the real environment, a precise description of the real environment should be prepared first before coming up with its counterpart in virtual reality. Aside from that, the environment should also be measured to depict an accurate version of it in the realm of virtual reality.

In addition, technological limitations of the present time are also challenges of creating systems from virtual reality. There are times that in creating designs, trackers are needed and small errors on these trackers could lead to mis-registrations. When sensors and trackers do not work accurately, this can affect the virtual reality system negatively. However, these are under the scope of hardware domain which means that the advancement of virtual reality also lies in the development of hardware technology combined with programs and systems which include virtual reality.

Although the future is unknown, many experts have predicted the future of virtual reality and these people believe that this technology is still in its early days which mean that can be further improved [7]. As the hardware companies enhance their products, it is expected that the virtual reality will be even close to reality. To make it more real, the sensors and trackers are expected to be better and many systems would involve more physical actions for the users to feel that they are like in the real world. In the field of architecture, it is expected that it will also be driven upward by virtual reality in which architects would build an artificial world where they can see and observe everything. The experts think that within five years, virtual architecture would be as much as convincing as the real thing. The 3-D imaging used in designs would be more interactive as if the model is already the real building with reading weather and surroundings [8].

2. Application of Virtual Reality

Virtual reality has taken a lot of people's interest in past few years. It is an existence of a new model of user interface; it provides excessive benefits in a lot of application fields. It offers an easy, great, and intuitive human-computer interaction. Users can observe and operate the simulated environment as in the real world, without having to understand how complex user interfaces work. It assisted in developing many applications, such as flight simulators, construction exercises or data visualization systems. Virtual reality is used as a remote operation and collaborative media, and of course it is also used in the entertainment field. Figure 1 illustrates the application of virtual reality in several aspects.

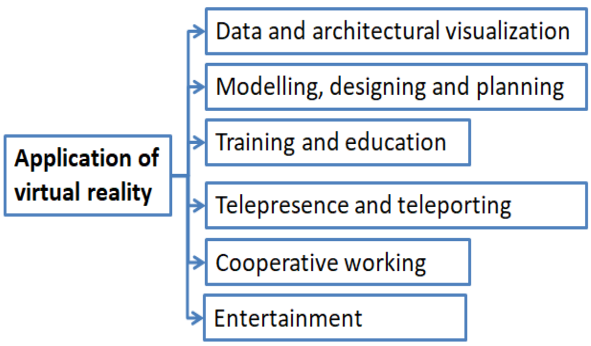

Figure 1. Virtual reality applications

2.1. Data and Architectural Visualization

Individuals have been collecting large amounts of data for a long time. Managing megabytes or even gigabytes of information is not easy. In order to take full advantage of it, special visualization techniques have been developed. Their objective is to create the data compelling and easy for humans to use. A desktop computer prepared with a visualization set and simple interface devices is beyond an ideal solution for data presentation and management. Virtual reality may provide a more built-in interface.

2.2. Modelling, Designing and Planning

In modeling, virtual reality provides the option to view the appearance of the presentation object in real-time and real space. For example, in a virtual design or a virtual kitchen developed as a tool for in-house designers, they can visualize their sketches. They can change the color, texture, and position of objects, and immediately observe the appearance of the entire environment. In addition, building information modeling (BIM) has greatly benefited architects because this advanced method has completely changed the way architects conduct architectural design, allowing architects to create digital design simulations to manage all information related to construction projects [9, 10].

2.3. Training and Education

In terms of training and education, the use of simulators has a long history and is generally regarded as the originator of virtual reality today. These application improvements are mainly used for military purposes. Many civilian companies now also use them because they provide lower operating costs and are safer than real aircraft flight training. In other systems that require training, simulation also provides great benefits. Therefore, they have been successfully applied to define the virtual reality training capabilities of rocket pilots by performing dangerous missions in space.

2.4. Telepresence and Teleoperating

Although the goal of remote control robots is to operate autonomously, they still need to be supervised by human operators in most cases. Telepresence is equipment that lets people to control in a remote environment through a virtual reality user interface. In most of the cases, this form of remote control is the only possible option; the remote environment may pose a danger to human health or life, and no other technology can support such a high degree of operational dexterity.

The system that uses a HMD also allows an expert to realize a microscope view, feel and control the sample surface. This system has been mentioned before the ophthalmic surgery system, and it can be considered: In addition to its training capabilities and remote operation, it provides precise surgical motion scaling, and is sometimes called a sub-manipulator.

2.5. Cooperative Working

All shared virtual environments and network-based may simplify the association between remote users. The use of higher bandwidth for information transfer is important for collaborative work. Multi-users of virtual reality focus on many research projects, such as NPSNET, AVIARY and etc. Although these plans are very promising, their practical value can be specified in practice. However, certain useful applications do now exist, such as a collaborative computer-aided design (CO-CAD) desktop system, which can help engineers work together in a shared virtual workstation. Other important examples of distributed virtual reality systems are training applications for multiple soldiers to inspect dangerous areas or astronauts to perform complex tasks in open space.

2.6. Entertainment

The declining price of hardware and the increasing power of hardware finally brought virtual reality to the public, and it has been applied in the entertainment field. W-Industry has successfully brought the network multiplayer game system to the market. Through these complex installations, the home entertainment market is rapidly expanding. Video game vendors like Sega and Nintendo sell simple virtual reality games, and there are more and more types of low-cost PC-based virtual reality devices.

3. Future in Virtual Reality

The upcoming of virtual reality is measured from two aspects: technology and society. The technology aspects include new research directions and their potential uses for scientific purposes. The social aspect includes the impact of new developments on people: individuals and society as a whole.

Virtual reality is a technology that allows users to interact with a computer-simulated environment, whether the environment is a simulation of the real world or a fictional world. It is essential to experience, feel and touch the past, present and future. This is the realm of creating the world, our customized reality. It covers creating video games to virtual walking on earth, from walking through a dream house to experiencing walking on alien planets. Through virtual reality, one can experience the most terrifying and difficult situations through the perspective of safety and learning.

The reputation of virtual technology is not limited to the IT field, but also derived from applications in many social fields, including economics, education, entertainment, communications, and manufacturing; as well as different applications, such as workplaces, smartphones, classrooms, and shopping activities. Virtual technology allows the leading capabilities of navigation functions, such as map applications and navigation in the virtual world, provides experiences in business and entertainment environments, such as shopping experience, provides educational applications, such as creativity in design training, and also provides the possibility of professional applications, such as medical operations as well as training and mechanical engineering.

4. Importance of Virtual Reality in Architecture

To understand virtual reality technologies, it is needed to enable new options or add value to existing options in architecture. Three conceptual levels are projected for categorizing and directing research and expansion in the area of virtual reality systems for architecture. These concepts include the technologies (systems), applications, and processes.

In technologies (systems), virtual reality systems can differ from desktop systems to facilities that contain one to six big projection screens. These are multifaceted arrangements of hardware and software with adequately of specific research and development challenges. In particular, requiring standards has formed a situation where the choice of any platform to be used as a development base seems to be a very uncertain choice for industrial applications.

In applications, experts have found many applications for virtual reality visualizations across many activities from early design reviews to marketing. It seems that this is about having new solutions to show and understand directly the performance of the built facility or environment, a facility still to be built, or the actual constructing process.

In processes, virtual reality in architecture is in new developing processes. The traditional processes can change or they show to be unnecessary and very new processes can occur. The technology revision that happens during this is neither generally not very well assumed nor has it been considered enough.

5. The Usage of Virtual Reality in Architecture

It is clear that the trends in the use of virtual reality for walkthroughs of visualization, analytical simulation such as energy, circulation, facilities management, and virtual reconstruction; design decision-making, collaboration, marketing; and construction are important and considered. Architecture is perhaps one of the best real applications for virtual reality. It can be used successfully to improve the familiarity of walking on a structure that does not exist. In addition, BMI further advances 2D and 3D CAD by combining 4-D (time) and 5-D (cost), allowing intelligent management of information throughout the project life cycle [9].

For example, blueprints only give a 2D representation of the building while 3D versions on a normal computer screen carry the spatial relation of a building in a very simple manner. Virtual reality allows experiencing the building in an immersive way that gives an almost real-life demonstration. In addition to visualizing the virtual environment, virtual reality can also be used as an instrument for building the environment itself.

This is a relatively new method of using virtual reality in architecture and is to prove its reasonableness. For example the application of Shadow Light Mirage project which is a third-generation software application that allows the creation and exploration of fully immersive domains in virtual reality. It gives user the ability to use space itself as the design medium, inspiring artistic innovation and greatly hastening the design process.

In analyzing the use of virtual reality in architecture, it is probable to see increased competence in daily productive use. It is considered the potential of Head-Mounted Displays (HMD), Computer Audio-visual Environment (CAVE) technologies, Single Wall Projection Displays / Power Walls, Workbenches and WIMPs (windows, icons, and menus, pointing) itemized in the descending level of immersion for possible practical applications in the practice of architecture. Figure 2 shows the virtual reality applications in architecture in the aspect of landscape, construction, interior design and exterior design.

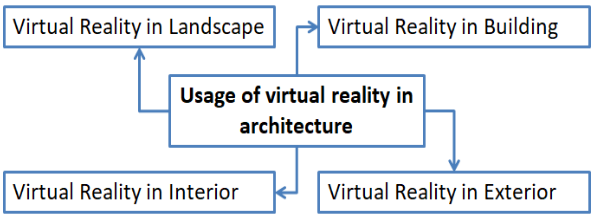

Figure 2. Application of virtual reality in architecture

5.1. Virtual Reality in Landscape

5.1.1. How Can We Use It?

Virtual reality (VR) offers the creation of and movement in virtual landscape environments that represent 3D versions of real landscapes. VR tools present new visualization technologies which allow landscape architects to generate VR environments and enable a great extent of movement in these virtual landscapes [11]. Furthermore, VR offers an immersive environment. It presents panoramic projections to fulfill the field of view and increase immersion in specific [12]. Digital three-dimensional systems can be used to determine the dimensions of panoramas for historic or contemporary landscapes too [12].

5.1.2. How Can It Effect Architecture?

Heim [13] and MacEachren et al. [14] offered four “I” factors in virtual environments which can affect architecture: “immersion, interactivity, information intensity, and intelligence of objects” [15].

Immersion refers to “a psychological state characterized by perceiving one to be enveloped by, included in, and interacting with an environment…” [16]. Architects can immerse in environments without physically being there. 3D-representation through VR may present the first immersive level, but have limitations of being constrained behind the computer [15]. Interactivity pertains to enabling users to engage with virtual environment, so that they can alter perspectives in these virtual settings [15]. Architects can interact with and experiment with virtual environments. Information intensity refers to detail levels through GeoVR, such as offering perspectives from different angles and viewpoints [15]. Intelligent objects can help architects in interpreting GeoVR environments [15]. Architects can use VR technologies to maximize access to virtual environments.

5.1.3. How Can Virtual Reality Be A Tool?

Virtual reality can be used as a tool in landscape through GeoVR. For instance, navigation can be done in GeoVR, where users walk virtually in the environment and assess spatial and object arrangements [15]. 3D scenes enable architects to view different points and measurements. Architects can use different projections, including top view and bird’s eye perspective, to monitor design options and final solutions [15]. Many VR viewers already offer these navigation abilities; for instance, SALIX adopts VRML viewers for this purpose [15].

5.1.4. Case Studies

One of the case studies focuses on CAVE. Joachim Kieferle simulated wind currents along buildings to generate a 3D completely immersive CAVE, “a virtual environment in real scale (1:1) with interactive simulations in real-time (25 images/second)” [11]. CAVE can then provide visibility to otherwise invisible elements in real-time settings, such as wind forces [11]. Kieferle asserted classical media remain largely static, due to emphasis on the state, while computers allow planners to consider the non-static and manifest processes, instead of states [11]. VR provides the ability to exhibit real conditions, apart from indicating the metadata or the abstract processes which will support the understanding of landscape objects [11].

The CAVE can be compared to use of Augmented Reality Systems in the medical and military fields [11]. They likewise offer the depiction of metadata in virtual environments. In addition, architects can use these systems to put on real-world feels to 3D graphical objects in a 3D virtual setting [11]. Such applications can make it simpler and easier to design and execute high-level CAVE environments with an increasing number of visible objects and other elements that they wish to contain in virtual environments [11].

5.2. Virtual Reality in Building

5.2.1. How Can We Use It?

Drawings cannot capture the 3D, spatial aspect of buildings. Designers and builders have been using physical models to help simulate the actual environment and the feel or physical dimensions of buildings [17]. Physical models take time to design and are very expensive to build, however [17]. Moreover, they are scale models with materials and colors that rarely represent real-life counterparts [17]. 3D printing helps make faster and efficient model buildings, but they cannot offer life-sized models [17]. Architects can use VR to generate a digital version of the environment and buildings. They can likewise be immersive and interactive, thereby facilitating both movement and efficient understanding of spatiality in buildings and their outside environment.

5.2.2. How Can It Effect Architecture?

New VR software and hardware enable immersive representations of environments, which include “gestural modeling, or the translation of hand movements captured via computer vision into design information” [18]. These tools permit designers to visualize and virtually dwell in 3D spatial environments at “full scale,” where they can conduct design work using intuitive hand and body movements [18]. Architects can produce novel interfaces and workflows [18]. In addition, these platforms can revitalize the participation of designers in digital design [18]. For example, wearing head-mounted displays (HMDs), like Oculus Rift DK2, can help architects produce a condition enabling “full scale” designs [18]. In this way, designers can go and move in the virtual context without using or making additional software workflows [18]. They can walk around a room (in virtual mode), for instance, and create designs that fit specific room needs. Architectural work can be easier and more engaging, which can reduce conflicts when the construction has started, as the immersion and interactivity in VR may eliminate gaps between architectural ideas and building limitations.

5.2.3. How Can Virtual Reality Be A Tool?

Virtual reality can be a tool for translating 3D geometry. VR tools can convert surface maps into a “walkable” environment that can be fully experienced through equipment, such as the Oculus Rift DK2 headset [18]. Architects can actually experience, determine and confirm design decisions by participating in the spatial aspects of the design through a one-to-one environment [18]. Moreover, these tools enable the production of diverse design solutions which may be altered in situ [18]. Some of the elements that can be changed or varied are natural and artificial lighting, layout of the furniture, and materiality [18].

Simulation models can be used inside the design process [18]. Consequently, models can offer greater freedom of movement, where designers can inspect and validate different viewpoints and control these views as well, such as through a connected Xbox 360 gaming controller [18]. From this approach, models can be represented as modest tonal values or substitutes for materials which can later be used or discarded for more formal project renderings [18].

5.2.4. Case Studies

An example would be RoundMe iOS/Android app. This can project “equirectangular panoramic renderings” which are subsequently positioned in spherical environments [18]. Consequently, they use the Google Cardboard mobile VR viewer in their smartphones to distribute the immersive environment of their virtual designs with team members [18]. Furthermore, architects can use the Google Photosphere application or other similar 360 photo applications to create photo spheres of construction sites and share them with other stakeholders including project consultants, contractors, and customers [18]. Such panoramic photos can record the construction process in more depth and allow project participants who cannot access the site to monitor the process and progress of the project through an immersive and interactive 3D environment.

5.3. Virtual Reality in Interior

5.3.1. How Can We Use It?

VR can be used to improve the immersion of the interior design, as well as collaboration. As in constructing landscape and buildings, a 3D virtual environment enables designers to be virtually in the place and design it with respect to real-life elements [19]. For example, designers can use VR to understand how sunlight and wind currents can impact the choices and designs for windows, doors, and other ornamental considerations. In addition, VR can be used to test furniture arrangement. Designers can access VR furniture databases and check how they can fit in the environments for both space and aesthetic considerations. Furthermore, VR can be used to improve collaboration with other stakeholders. Designers can show the virtual design to clients, either face to face or online. From there, clients can provide feedback to the VR model [19].

5.3.2. How Can It Effect Architecture?

VR can affect architecture through improved collaboration with other designers and clients [20]. Traditional CAD software is not made to offer different kinds of representations for interior designers [20]. The combination of BMI and VR allows them to be immersed in a 3D environment, as well as interact with fellow designers and clients in the process of choosing and arranging furniture and other interior objects [9, 20]. Anderson et al. offered an environment for conceptual design in architecture [20]. They designed and executed an immersive virtual environment that follows dimensions of a characteristic designer’s work area via a ‘kiosk’ toolbox [20]. This design setting permits the addition and assignment of images, 3D items, and videos on any surface in order to create a larger contextual environment and to enable work in more than one scale concurrently [20].

5.3.3. How Can Virtual Reality Be A Tool?

VR can be used as a tool for interior space design through offering the advantages of advanced visualization and interaction capabilities [20]. VR either offers or allows the use of tools for developing and accessing design concepts in 3D [20]. It can be a tool for reaching a more detailed design of the interior space, as well as better refinement of concepts through tools for accurate scaling, positioning and alignment of objects [20]. The 3D modeling applications should enable direct manipulation in 3D and the ability to adapt the values of the geometric properties and relations of the elements, such as position, size, and space from a certain reference points [20].

5.3.4. Case Studies

An example is the case from Vosinakis et al. [20], where they designate the design and implement a desktop 3D environment for imagining interior spaces. It permits users to interactively design a room and put furniture and electric appliances. Likewise, it backs up design businesses through enabling users to preview products before making final purchasing decisions [20]. The implementation results in a web-based environment offers 2D interface for the interactive design of the room and the furniture placement. Subsequently, it is producing a 3D environment that allows preview of and alternations in the interior design concept [20].

5.4. Virtual Reality in Exterior

5.4.1. How Can We Use It?

VR can be used to ensure the interdependence and balance between interior and exterior designs [21]. CAD packages are insufficient in rendering 3D images. Thus, there is a need for VR and BMI. Architects can use augmented reality in designing the exterior of buildings using the bird-eye view [21]. Moreover, VR can enable architects to find out how changes in exterior aspects influence interior decisions too (e.g. increasing ceiling size affects interior design). Hence, designers can use VR through imagining outer spaces and how interior and exterior designs impact each other, while likewise considering external elements that impact exterior decisions.

5.4.2. How Can It Effect Architecture?

Architects can use augmented reality in designing the exterior of buildings. They can use virtual avatars to render interior designs and then become more aware of materializing these designs [21]. These avatars can serve as a connection between augmented reality and VR environments [21]. Furthermore, VR can affect architecture's ability to collaborate with other designers in making the exterior design. Similar to interior design, architects can consult with other stakeholders, so that exterior design can be both realistic and reflect wider stakeholder approval.

5.4.3. How Can Virtual Reality Be A Tool?

VR can be a tool for exterior design through a realistic understanding of external forces and internal-external dynamics. As a tool, it can improve comprehension and appreciation for external environmental forces that can act on exterior designs [20]. Furthermore, VR can help change the exterior, while reflecting connections or balance with the interior [21]. For instance, even if interior designers may not see the exterior of the building, they can access some parameters including ceiling height and wall materials [21]. Changing these parameters affect interior design too. Hence, architects become more aware of how their actions impact interior frameworks [20].

5.4.4. Case Studies

A case study shows collaborative design efforts. Wang [21] demonstrated that mixed reality boundaries can support real-time cooperation between architects and interior designers. They can work more closely and see how their actions can impact one another (e.g. changes inside and outside can affect each other's designs). Finally, another case study demonstrated specification of design objects [20]. Determining external properties through VR can make interior design more efficient too. As it noted, predetermined functions and semantics improved object classification and layout for exterior and interior designs [20].

6. Challenges of Virtual Reality in Architecture and Education

First of all, the challenges of virtual reality in the architecture and the realization of the industrial problems of the system in the architecture are the three major challenges faced by system developers: the extraction of industrial domain knowledge, the preparation of real models, and technical limitations. These challenges can be divided into several areas, as shown in Figure 3.

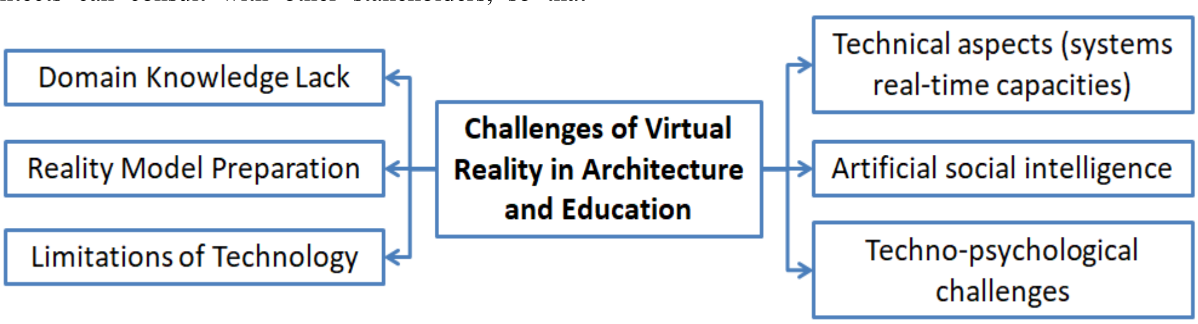

Figure 3. Challenges of virtual reality in the field of architecture and education

6.1. Domain Knowledge Lack

When constructing facilities, a large amount of design and completion information is created in various professional services such as mechanical, electrical, structural, and etc. Unfortunately, a lot of information is currently represented and stored in the form of 2D drawings rather than 3D models in practice. Obviously there is a lack of a well-structured integrated 3D database, which can be easily used by virtual reality systems to support the extraction of information sources. This is mainly because the designer does not promise to provide information.

6.2. Reality Model Preparation

To register digital information in the real environment, the virtual reality system needs to obtain an accurate description of the real environment: a real model [22]. A relatively accurate reality model can be defined for the accurately measured environment. An important issue in the development of virtual reality systems for architecture and design is the application of systems and accurate methods to create such reality models.

6.3. Limitations of Technology

Limitations of technology are still the major problem for virtual reality systems. Virtual reality needs highly precise monitor because even little monitor faults can result in obvious mis-registrations between real and virtual entities [23]. In addition, the main problem to build effective virtual reality systems is the necessity of precise and remote sensors and monitors that report the positions of the user and the nearby entities in the environment [23]. The development of tracking and sensing technology largely depends on industrial and academic efforts in the hardware field. In education, there are also some challenges that hinder the advancement of virtual reality as shown in Figure 4.

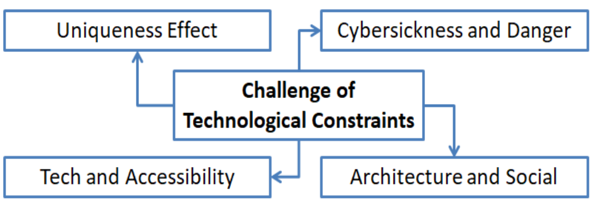

Figure 4. Challenges hindering the development of virtual reality

6.3.1. Challenge: Uniqueness effect

It is possible that any observed improvements in performance and engagement in learners that use virtual reality would be due to the novelty effect, which is the tendency for performance to improve initially when a new technology is instituted. This has been seen with e-learning devices like computer-assisted education. The worst-case scenario is that learners get so used to virtual reality in school, and perhaps in their daily lives, that it loses its appeal completely. While definitely a concern, this is a bit of a moot point because in the end a teacher should use virtual reality not because it is the shiny new toy but because it delivers a better learning experience for learners. It is believed that as it becomes more pervasive, virtual reality will show some novelty effect. It will provide learners with a better experience of content than current alternatives.

6.3.2. Challenge: Cybersickness and danger

For the future of virtual reality in any domain, cybersickness is the elephant in the room. It is a sensation similar to motion sickness that may happen during or after a virtual reality experience. This would be particularly problematic in an education space since sick learners do not make expert learners. Like motion sickness, the presence of indications differ from person to person with gender, ethnicity, and age all possible contributors. Additionally, if motion sickness truly is an exact model, then it would expect 2 - 12 year old users to experience the most cybersickness, which would make applying virtual reality in primary school problematic. With the perceived or very possible for children to get sick or hurt, it will be motivating to see if managers, instructors, and parents sight on virtual reality as too dangerous for a classroom environment.

6.3.3. Challenge: Tech and accessibility

Today, virtual reality technology is not widely available. The fastest and cheapest way to get the tech into classroom is with a smartphone and Google Cardboard. If learners are allowed to use their computers in class, instructors could apply this great option today. Nevertheless, the library of content is still at its beginning and it is not explicitly 'educational'. Virtual reality in education will be closely tied to the success of the merged learning, producer, and movements of ed-tech that inspire instructors to see the educational value of a variety of media and tech tools and a footpath to virtually applying them.

6.3.4. Challenges in architecture and social

Virtual reality is still unable to create a real life experience in many ways. This is almost true when introducing the "social dimension" into the virtual world. However, it is clear that creating convincing virtual characters and virtual others, conveying meaningful and appropriate social behaviors is still an open challenge for virtual reality in the future. This challenge involves both technical aspects, such as the real-time capabilities of the system, and psychological aspects, such as human communication mechanisms. Virtual reality systems still have shortcomings in social perception, although the social dimension is crucial when labeling autonomous agents with certain social background intelligence.

These cope with technical and psychological challenges, these challenges may be difficult or even difficult to deal with. There are many examples of social meaning models that can only be compelling at the dual level, the ultimate meaning of which is encoded in temporal possibilities. These aspects of interpersonal synchronization reflect the emerging fields and greatest challenges of social psychology and social neuroscience. The limitations of these operations certainly mean physical boundaries and applicability, as well as the level of intervention in human differences and gestures. Finding these levels of intervention is a challenging task for interdisciplinary attitudes. The transfer of intangible ideas to technical psychological implementation is an open question.

6.4. Technical Aspects (Systems Real-Time Capacities)

Once users choose their virtual personas, they will be able to beam from virtual space to virtual space and contact socially with other real people from the safety of their fake avatar personalities. Virtual reality technology will map every movement, including the facial expressions. In some cases, it will mechanize a movement like walking, while imitating the movement of the faces, heads, hands and upper body. Virtual reality social interactions will take place in remote and amazing places, on unsociable planets, under water, at historic sites, etc.

6.5. Artificial Social Intelligence

Taking into account the specific advantages and disadvantages of humans and machines, the concept of social virtual reality is turned to focus on hybrid avatar-agent systems. These systems are necessary to generate i) virtual avatar interactions between real people, using their social perception and flexible communication skills, and ii) an artificial social intelligence (AIS) that regulates or transforms continuous virtual avatars based on social signs interaction, such as performing behavioral manipulation in adaptive cross-cultural discussions.

Most system developers focus on artificial intelligence; goal to create independent computer agents that can be used as social partners or dialogue interfaces in human-computer interaction [24]. The primary challenge here is to develop an artificial intelligence core that has typical human perception, cognition and behavior skills.

6.6. Techno-Psychological Challenges

The application of the hybrid avatar agent technology (HAAT) interface metaphor challenges computer scientists, engineers and psychologists. First, the artificial intelligence and synchronization module must identify the relevant behavioral and neurophysiological signs of successful communication within the two-tuple, as well as interpersonal phenomena. This supervised knowledge includes access to relevant data from many sources; it includes artificial intelligence-based algorithms specifically designed to improve knowledge and insights about continuous interaction [24]. Second, the platform must have real-time capabilities to meet the deadlines for perception tasks in people's communication. Since the two time-critical aspects depend on real-time, real-time capability is crucial. These aspects can be expressed as the inner aspects of the coupling of action insights, leading to perceived body ownership and agency experience, the interpersonal aspects of social events and the interaction of different signal types, and the close coupling of action and reaction time in phenomena. Time synchronization implies the phenomenon of synchronization, coexistence and social existence.

The psychological aspects of users also define certain non-functional requirements, especially the time requirements of the typical tightly coupled human-computer interaction cycle in virtual reality. For example, visual motion events are a key bottom-up interpersonal factor in several ways, from accepting avatar images to generating reliable viewpoint and view corrections, such as head tracking and avoiding simulator diseases [25]. Nevertheless, chipset designs and operating systems have mostly given up the challenge of implementing real-time operating systems for commercial use, although the concepts and designs come from other ideas, such as the mobile platform Android.

7. Conclusion

In the future, virtual reality technology is expected to have the leading ability to provide navigation functions. For example, map applications and navigation functions in the virtual world. Next, provide experiences in business and entertainment environments. Similarly, provide shopping experience and educational applications, such as creativity in design training. The future vertical reality will also provide possibilities for special applications, for instance, medical operations and physical activity and mechanical engineering.

This study has highlighted the application of virtual reality, future in virtual reality, importance of virtual reality in architecture, and the use of virtual reality in architecture along with case studies. The challenges of virtual reality in architecture and education were critically outlined in the aspect of the domain lack of knowledge, reality model preparation, the limitations of technology, system real-time capacities, artificial social intelligence and techno-psychological challenges. By overcoming these challenges, the realization of virtual reality in the architecture can be achieved. The advantages of VR and BIM are very significant. Architects, customers, builders and engineers can be integrated into one platform, and they can go beyond basic design principles and gain insight into the future of design.

Acknowledgements

The authors are very grateful for the guidance of educators and resource support provided by the College of Architecture and Design, as well as the library of Effat University.

REFERENCES

[1] What is Virtual Reality. Virtual Reality Society, 2016, Online available from http://www.vrs.org.uk/virtual-reality/what-is-virtual-reality.html

[2] History of Virtual Reality. Virtual Reality Society, 2016, Online available from http://www.vrs.org.uk/virtual-reality/history.html

[3] Types of Virtual Reality. SEWETN Project Team, Online available from http://resources.hwb.wales.gov.uk/VTC/ngfl/2007-08/ict/understanding-virtual-reality-imslrn/page_03.htm

[4] M. Alzara. Virtual Rebuilding and Documentation of the Historical Old Market of Domat Al-Jandal City, Civil Engineering and Architecture, Vol. 9, No. 2, pp. 512 - 522, 2021, DOI: 10.13189/cea.2021.090224

[5] M. Ebru Erdonmez Dincer , C. Abdi Guzer. The Boundaries of Representation of Architecture and Art in Public Space, International Architecture Biennial, Civil Engineering and Architecture, Vol. 8, No. 1, pp. 9 - 20, 2020, DOI: 10.13189/cea.2020.080102

[6] X. Y. Wang. Augmented Reality in Architecture and Design: Potential Challenges for Applications, International Journal of Architectural Computing, Vol. 2, No. 7(2007), 309-326, 2007.

[7] L. Eadicicco. 3 Things the Know About the Future of Virtual Reality, Time, 2016, Online available from http://time.com/4324598/alienware-interview-virtual-reality/

[8] R. V. Hooijdonk. The Future of Architecture and Construction is All About Virtual Reality, Richard Van, 2016, Online available from https://en.richardvanhooijdonk.com/future-architecture-construction-virtual-reality/

[9] J. Tomás Franco. What is BIM and Why Does it Seem to be Fundamental in the Current Architectural Design?, 2018, Online available from https://www.archdaily.com/888727/what-is-bim-and-why-does-it-seem-to-be-fundamental-in-the-current-architectural-design

[10] N. Reyes. Building Information Modeling Benefits for Architecture and Construction, 2019, Online available from https://hmcarchitects.com/news/building-information-modeling-benefits-for-architecture-and-construction-2019-06-05/

[11] U. Nothhelfer. Landscape Architecture in the Reality-Virtuality. Online available from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.526.7107&rep=rep1&type=pdf

[12] E. Lange, and I. D. Bishop. Communication, Perception and Visualization, Visualization in Landscape and Environmental Planning: Technology and Applications, 3-22, 2005.

[13] M. Heim. Virtual realism. New York, New York: Oxford, 1998.

[14] M. MacEachren, R. Edsall, D. Haug, R. Baxter, G. Otto, R. Masters, S. Fuhrman, and L. Qian. Exploring the potential of virtual environments for geographic visualization, 1999, Online available fromhttp://www.geovista.psu.edu/publications/aag99vr/fullpaper.htm

[15] V. R. Lammeren, V. Clerc, H. Kramer, and A. Ligtenberg. Virtual Reality in the Landscape Design Process, 2002, Online available from http://edepot.wur.nl/187048

[16] B.G. Witmer, and M. J. Singer. Measuring pressure in virtual environments: A presence quetionaire, Presence, Vol. 7, No. 3, 225-240, 1998.

[17] Heiskanen. How is Virtual Reality being used in the Construction Industry?, VR & AR World, 2016, Online available from https://vrarworld.wordpress.com/2016/09/06/virtual-reality-in-construction/

[18] Mahon. 4 Ways Virtual and Augmented Reality Will Revolutionize the Way We Practice Architecture, Archdaily, 2016, Online available from http://www.archdaily.com/783677/4-ways-virtual-and-augmented-reality-will-revolutionize-the-way-we-practice-architecture

[19] T. Korpipää, K. Minami, T. Kuroda, Y. Manabe, K. Chihara, and T. Nara. Shared Virtual Reality Interior Design System, 2000, Online available from https://pdfs.semanticscholar.org/7889/aed82450054730f50ccee93eba03be9ae1ab.pdf?_ga=2.203338769.1032107180.1599385016-1518013640.1582610120

[20] S. Vosinakis, P. Azariadis, N. S. Sapidis, and S. Kyratzi. A Virtual Reality Environment Supporting the Design and Evaluation of Interior Spaces, 2007. Online available from https://pdfs.semanticscholar.org/84c1/5ffa62d5504b4035ef7c67768a26e19dd187.pdf

[21] X. Y. Wang. Implementation and Experimentation of a MR Collaborative Design Space, Computer Supported Cooperative Work in Design IV: 11th International Conference, CSCWD 2007, 111-122, 2008, DOI=10.1007/978-3-540-92719-8_11

[22] G. Klinker, D. Stricker, and D. Reiners. Virtual Reality for exterior construction applications, Fundamentals of Wearable Computers and Augmented Reality, 379-427, 2001.

[23] R. T. Azuma. A survey of Virtual Reality, Presence: Teleoperators and Virtual Environments, MIT Press, Vol. 6, No. 4, 355-385, 1997.

[24] M. E. Latoschik, and M. Fischbach. Engineering Variance: Software Techniques for Scalable, Customizable, and Reusable Multimodal Processing, M. Kurosu (Hrsg.), Human Computer Interaction, Part I, HCI 2014, Vol. 8510, 308-319, 2014.

[25] J. L. Lugrin, J. Latt, and M. Latoschik. Avatar Anthropomorphism and Illusion of Body Ownership in VR, 2015, DOI=10.1109/VR.2015.7223379.